# TURKISH GREENHOUSE GAS INVENTORY 1990 - 2018

National Inventory Report for submission under the United Nations Framework Convention on Climate Change

TURKISH STATISTICAL INSTITUTE

April 2020

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# EXECUTIVE SUMMARY

## ES.1 Background Information on Greenhouse Gas Inventories

The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty established in 1992 to cooperatively address climate change issues. The ultimate objective of the UNFCCC is to stabilize atmospheric greenhouse gas (GHG) concentrations at a level that would prevent dangerous interference with the climate system. Turkey ratified the UNFCCC in May 2004.

To achieve its objective and implement its provisions, the UNFCCC lays out several guiding principles and commitments. Specifically, Articles 4 and 12 commit all Parties to develop, periodically update, publish and make available to the COP their national inventories of anthropogenic emissions by sources and removals by sinks of all GHGs not controlled by the Montreal Protocol.

Turkey's National Inventory is prepared and submitted annually to the UNFCCC by April 15 of each year, in accordance with revised Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories (UNFCCC Reporting Guidelines). The annual inventory submission consists of the National Inventory Report (NIR) and the Common Reporting Format (CRF) tables.

Turkey, as an Annex I party to the United Nations Framework Convention on Climate Change (UNFCCC), reports annually on greenhouse gas (GHG) inventories. This National Inventory Report (NIR) contains national GHG emission/removal estimates for the period of 1990-2018.

Pursuant to Decision 24/CP.5, all Parties listed in Annex I of the UNFCCC are required to prepare and submit annual NIR containing detail and complete information on the entire process of preparation of such GHG inventories. The purpose of such reports is to ensure the transparency, accuracy, consistency, comparability and completeness of inventories and support the independent review process.

This inventory submission follows the revised UNFCCC Reporting Guidelines, adopted through Decision 24/CP.19 at COP 19.

Together with the common reporting format (CRF) tables, Turkey submits a NIR, which refers to the period covered by the inventory tables and describes the methods and data sources on which the pertinent calculations are based. The report, and the CRF tables, have been prepared pursuant to the UNFCCC guidelines on annual inventories (24/CP.19) and in conformance with the 2006

Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas (GHG) Inventories (2006 IPCC Guidelines).

The annual GHG inventory provides information on the trends in national GHG emissions and removals since 1990. This information is essential for the planning and monitoring of climate policies.

The Turkish Statistical Institute (TurkStat) is the responsible agency for compiling the National GHG Inventory. Turkey's GHG emissions inventory is prepared by "GHG Emissions Inventory Working Group" which is set up by the decision of the Coordination Board on Climate Change (CBCC). TurkStat is the responsible organization for the coordination of working group (WG). Moreover, TurkStat has been designated as the National inventory focal point of Turkey by the decision taken by CBCC in 2009.

The Official Statistics Programme (OSP), based on the Statistics Law of Turkey No. 5429, has been prepared for a 5-year-period in order to determine the basic principles and standards dealing with the production and dissemination of official statistics and to produce reliable, timely, transparent and impartial data required at national and international level. The responsibility for compiling the National GHG Inventory has also been given to TurkStat by the OSP. The inventory preparation is a joint work of GHG emission inventory WG.

The main institutions involved in GHG inventory are;

- Turkish Statistical Institute (TurkStat),
- Ministry of Energy and Natural Resources (MENR),
- Ministry of Transport and Infrastructure (MoTI),
- Ministry of Environment and Urbanization (MoEU),
- Ministry of Agriculture and Forestry (MoAF).

The National GHG emissions/removals are calculated by using 2006 IPCC Guidelines. The Emission Inventory includes direct GHGs as carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), fluorinated gases (F-gases); Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulphur hexafluoride ($SF_6$), $NF_3$ and indirect GHGs as nitrogen oxides ($NO_x$), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), and Sulphur dioxide ($SO_2$) emissions originated from energy, industrial processes and product use (IPPU), agriculture and waste. The emissions and removals from land use, land use change and forestry (LULUCF) are also included in the inventory.

## ES.2 Summary of National Emission and Removal Related Trends

Turkey's total GHG emissions, excluding the LULUCF sector, were estimated to be 520.9 Mt of $CO_2$ equivalent ($CO_2$ eq.) in 2018. This represents a decrease of 2.8 Mt, or 0.5%, in emissions compared to 2017, and a 137.5% increase compared to 1990 (Table ES 1).

**Table ES 1 Greenhouse gas emissions, 1990-2018**

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| Total emissions (Mt $CO_2$ eq. exc. LULUCF) | 219.4 | 247.8 | 298.8 | 337.1 | 398.9 | 472.6 | 497.7 | 523.8 | 520.9 |
| Change compared to 1990 (%) | - | 12.9 | 36.2 | 53.7 | 81.8 | 115.4 | 126.9 | 138.8 | 137.5 |
| Net emissions (Mt $CO_2$ eq. inc. LULUCF) | 163.6 | 190.4 | 237.2 | 262.5 | 325.5 | 375.3 | 401.8 | 423.9 | 426.4 |
| Change compared to 1990 (%) | - | 16.4 | 45.0 | 60.5 | 98.9 | 129.4 | 145.6 | 159.1 | 160.6 |

Turkey's total GHG emissions, including the LULUCF sector, were 426.4 Mt $CO_2$ eq. in 2018. Thus, LULUCF included total emissions increased 0.6% as compared to 2017 emissions. There is a 160.6% increase from 1990 to 2018 (Table ES 1).

**Table ES 2 Overview of GHG emissions and removals, 1990-2018**

**(Mt $CO_2$ eq.)**

| GHG emissions | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ (excluding LULUCF) | 151.5 | 180.9 | 229.8 | 264.2 | 314.4 | 381.3 | 401.2 | 425.3 | 419.2 |
| $CO_2$ (including LULUCF) | 95.6 | 123.4 | 168.0 | 189.5 | 240.9 | 284.0 | 305.2 | 325.3 | 324.5 |
| $CH_4$ (excluding LULUCF) | 42.4 | 42.5 | 43.6 | 45.2 | 51.3 | 51.4 | 53.9 | 54.2 | 57.6 |
| $CH_4$ (including LULUCF) | 42.5 | 42.5 | 43.7 | 45.2 | 51.3 | 51.4 | 53.9 | 54.3 | 57.6 |
| $N_2O$ (excluding LULUCF) | 24.8 | 23.7 | 24.7 | 26.1 | 29.6 | 35.0 | 37.4 | 38.8 | 38.9 |
| $N_2O$ (including LULUCF) | 24.9 | 23.8 | 24.8 | 26.1 | 29.6 | 35.1 | 37.5 | 38.9 | 39.0 |
| HFCs | NO | NO | 0.1 | 1.1 | 3.1 | 4.6 | 5.0 | 5.2 | 5.1 |
| PFCs | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.2 | 0.1 | 0.1 | 0.0 |
| $SF_6$ | NO | NO | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Total (excluding LULUCF) | 219.4 | 247.8 | 298.8 | 337.1 | 398.9 | 472.6 | 497.7 | 523.8 | 520.9 |
| Total (including LULUCF) | 163.6 | 190.4 | 237.2 | 262.5 | 325.5 | 375.3 | 401.8 | 423.9 | 426.4 |

Total GHG emissions as $CO_2$ eq. for the year 2018 were 520.9 Mt (excluding LULUCF). In overall 2018 emissions, the energy sector had the largest portion with 71.6%. The energy sector was followed by the sectors of IPPU with 12.5%, the agriculture with 12.5% and the waste with 3.4%. GHG emissions by sectors are given in Table ES 3.

**Table ES 3 Greenhouse gas emissions by sectors, 1990-2018**

**(Mt $CO_2$ eq.)**

| Year | Energy | IPPU | Agriculture | LULUCF | Waste | Total (Excluding LULUCF) | Total (Including LULUCF) |
|---|---|---|---|---|---|---|---|
| 1990 | 139.6 | 22.8 | 45.8 | -55.8 | 11.1 | 219.4 | 163.6 |
| 1991 | 144.0 | 24.7 | 46.7 | -56.7 | 11.3 | 226.8 | 170.0 |
| 1992 | 150.3 | 24.3 | 46.8 | -56.8 | 11.5 | 233.0 | 176.2 |
| 1993 | 156.8 | 24.5 | 47.2 | -56.0 | 11.8 | 240.3 | 184.3 |
| 1994 | 153.3 | 24.2 | 44.7 | -57.4 | 12.0 | 234.3 | 176.9 |
| 1995 | 166.3 | 25.2 | 43.8 | -57.4 | 12.3 | 247.8 | 190.4 |
| 1996 | 184.0 | 26.2 | 44.5 | -57.7 | 12.7 | 267.4 | 209.7 |
| 1997 | 196.2 | 27.0 | 42.3 | -61.7 | 13.2 | 278.6 | 216.9 |
| 1998 | 195.9 | 27.4 | 43.5 | -62.6 | 13.5 | 280.2 | 217.6 |
| 1999 | 193.8 | 25.8 | 44.1 | -64.0 | 13.9 | 277.7 | 213.6 |
| 2000 | 216.1 | 26.2 | 42.1 | -61.6 | 14.3 | 298.8 | 237.2 |
| 2001 | 199.2 | 25.9 | 39.7 | -64.7 | 15.5 | 280.3 | 215.6 |
| 2002 | 205.8 | 26.9 | 37.4 | -72.5 | 15.9 | 286.0 | 213.5 |
| 2003 | 220.3 | 28.2 | 40.5 | -74.5 | 16.2 | 305.3 | 230.7 |
| 2004 | 226.1 | 30.8 | 41.1 | -73.6 | 16.6 | 314.7 | 241.0 |
| 2005 | 244.0 | 33.6 | 42.2 | -74.7 | 17.3 | 337.1 | 262.5 |
| 2006 | 260.0 | 36.7 | 43.6 | -74.7 | 18.0 | 358.3 | 283.6 |
| 2007 | 290.8 | 39.2 | 43.2 | -74.4 | 18.3 | 391.4 | 317.1 |
| 2008 | 287.3 | 40.9 | 41.0 | -69.2 | 18.4 | 387.6 | 318.4 |
| 2009 | 292.5 | 42.5 | 41.8 | -72.8 | 18.8 | 395.6 | 322.8 |
| 2010 | 287.0 | 48.1 | 44.1 | -73.4 | 19.5 | 398.9 | 325.5 |
| 2011 | 308.7 | 52.8 | 46.6 | -77.1 | 19.8 | 427.8 | 350.8 |
| 2012 | 320.5 | 55.1 | 52.3 | -74.5 | 19.4 | 447.3 | 372.8 |
| 2013 | 307.5 | 58.1 | 55.5 | -76.5 | 18.2 | 439.3 | 362.8 |
| 2014 | 325.8 | 58.6 | 55.9 | -77.5 | 18.2 | 458.4 | 380.9 |
| 2015 | 340.9 | 57.1 | 55.8 | -97.3 | 18.8 | 472.6 | 375.3 |
| 2016 | 359.7 | 61.1 | 58.5 | -95.9 | 18.4 | 497.7 | 401.8 |
| 2017 | 379.9 | 63.6 | 62.8 | -99.9 | 17.4 | 523.8 | 423.9 |
| 2018 | 373.1 | 65.2 | 64.9 | -94.6 | 17.8 | 520.9 | 426.4 |

IPPU: Industrial Processes and Product Use
LULUCF: Land Use, Land Use Change and Forestry

As shown in Table ES 3, emissions from energy decreased by 1.8% to 373.1 Mt $CO_2$ eq. in 2018 as compared to 2017. However, there is 167% increase as compared to 1990. Emissions in the IPPU sector increased to 65.2 Mt $CO_2$ eq. in 2018 which is 2.5% higher than the emissions in 2017. Emissions in the agriculture and waste sectors were 64.9 and 17.8 Mt $CO_2$ eq. respectively in 2018.

## ES.3 Overview of Emission Estimates and Trends

The highest portion of total $CO_2$ emissions originated from energy sector with 85.8%. The remaining 13.9% originated from IPPU and 0.3% from agriculture in 2018. $CO_2$ emissions from energy decreased 1.9% compared to 2017 while increased 177% as compared to 1990. $CO_2$ emissions from industrial processes increased 2.0% compared to 2017 and increased 175% as compared to 1990.

The largest portion of $CH_4$ emissions originated from agriculture with 63.1% while 20.3% from waste, and 16.6% from energy and industrial processes. $CH_4$ emissions from agriculture increased 7.6% compared to 2017. It increased 45.1% as compared to 1990. $CH_4$ emissions from waste increased 0.7% compared to 2017. However, it increased 21.5% as compared to 1990.

While 70.1% of $N_2O$ emission was from agriculture, 15.7% was from waste, 9.5% was from energy and 4.7% was from IPPU. There is a 0.2% increase and 56.8% increase in total $N_2O$ emissions as compared to 2017 and 1990 respectively. GHG emissions by sectors are given in Table ES 4.

**Table ES 4 GHG emissions, 1990-2018**

**(kt)**

| Emission sources | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **$CO_2$** | | | | | | | | | |
| **Total** | 151 508 | 180 903 | 229 791 | 264 201 | 314 380 | 381 332 | 401 240 | 425 329 | 419 195 |
| Energy | 129 882 | 156 827 | 204 511 | 232 409 | 270 820 | 329 782 | 345 298 | 366 898 | 359 819 |
| IPPU | 21 140 | 23 624 | 24 641 | 31 167 | 42 904 | 50 738 | 54 645 | 56 980 | 58 117 |
| Agriculture | 460 | 426 | 617 | 613 | 645 | 811 | 1 295 | 1 450 | 1 257 |
| Waste | 27 | 26 | 21 | 12 | 11 | 1.1 | 1.8 | 1.5 | 1.2 |
| **$CH_4$** | | | | | | | | | |
| **Total** | 1 696 | 1 700 | 1 742 | 1 806 | 2 053 | 2 054 | 2 154 | 2 169 | 2 303 |
| Energy | 311 | 286 | 361 | 338 | 491 | 296 | 420 | 356 | 383 |
| IPPU | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.6 | 0.7 | 1 | 1 |
| Agriculture | 1 001 | 984 | 874 | 881 | 950 | 1 212 | 1 216 | 1 350 | 1 453 |
| Waste | 384 | 430 | 507 | 587 | 611 | 546 | 518 | 463 | 467 |
| **$N_2O$** | | | | | | | | | |
| **Total** | 83 | 80 | 83 | 87 | 99 | 118 | 126 | 130 | 131 |
| Energy | 6.5 | 7.8 | 8.5 | 10 | 13 | 12 | 13 | 14 | 12 |
| IPPU | 3.6 | 3.4 | 2.8 | 2.4 | 5.5 | 4.9 | 4.1 | 4.2 | 6.1 |
| Agriculture | 68 | 63 | 66 | 66 | 66 | 83 | 90 | 93 | 92 |
| Waste | 4.9 | 5.3 | 5.5 | 8.8 | 14 | 17 | 18 | 20 | 20 |

IPPU: Industrial Processes and Product Use

## ES.4 Indirect GHG Emissions

Emissions of CO, $NO_x$, NMVOC and $SO_2$ are also included in the report because they influence climate change indirectly. Table ES 5 shows the indirect GHG emissions. CO emissions are 1.60 Mt in 2018 with almost 99% of them from energy sector. $NO_x$ emissions are 0.78 Mt in 2018 and more than 99% of which is from energy. NMVOC emissions are 0.99 Mt in 2018. The largest portion of NMVOC emissions is from agriculture with 49% and this figure is followed by IPPU with 27%. $SO_2$ emissions are 2.5 Mt and almost 100% is sourced from energy sector in 2018.

**Table ES 5 Indirect GHG emissions, 1990-2018**

**(kt)**

| Emission sources | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **CO** | | | | | | | | | |
| **Total** | **2 043** | **5 762** | **8 763** | **3 746** | **3 426** | **2 482** | **2 288** | **2 115** | **1 596** |
| Energy | 2 000 | 5 730 | 8 697 | 3 724 | 3 406 | 2 468 | 2 262 | 2 082 | 1 578 |
| IPPU | 8.60 | 8.75 | 8.54 | 8.12 | 7.33 | 8.40 | 10.76 | 10.56 | 10.56 |
| Waste | 16.41 | 22.61 | 19.99 | 9.74 | 7.48 | 0.39 | 0.56 | 0.56 | 0.56 |
| **$NO_x$** | | | | | | | | | |
| **Total** | **255** | **1 041** | **1 492** | **1 301** | **956** | **801** | **805** | **778** | **783** |
| Energy | 252 | 1 030 | 1 482 | 1 297 | 953 | 797 | 801 | 773 | 779 |
| IPPU | 0.95 | 9.53 | 7.62 | 3.60 | 2.77 | 3.70 | 3.52 | 3.80 | 4.06 |
| Waste | 0.93 | 1.29 | 1.14 | 0.55 | 0.43 | 0.02 | 0.03 | 0.03 | 0.03 |
| **NMVOC** | | | | | | | | | |
| **Total** | **829** | **1 231** | **1 526** | **1 024** | **1 014** | **1 014** | **990** | **1 014** | **989** |
| Energy | 283 | 651 | 906 | 428 | 407 | 305 | 275 | 252 | 198 |
| IPPU | 184 | 202 | 236 | 227 | 239 | 251 | 256 | 261 | 264 |
| Agriculture | 356 | 360 | 354 | 336 | 332 | 414 | 419 | 461 | 487 |
| Waste | 4.92 | 18.13 | 30.25 | 32.55 | 35.55 | 44.01 | 39.87 | 39.9 | 40.5 |
| **$SO_2$** | | | | | | | | | |
| **Total** | **1 687** | **1 844** | **2 238** | **2 001** | **2 555** | **1 947** | **2 251** | **2 361** | **2 524** |
| Energy | 1 687 | 1 843 | 2 237 | 2 000 | 2 554 | 1 946 | 2 250 | 2 360 | 2 524 |
| IPPU | 0.73 | 0.75 | 0.70 | 0.63 | 0.54 | 0.69 | 0.82 | 0.85 | 0.85 |
| Waste | 0.03 | 0.04 | 0.04 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |

IPPU: Industrial Processes and Product Use

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| 2006 IPCC Guidelines | 2006 IPCC Guidelines for National Greenhouse Gas Inventories |
| ABPRS | Address Based Population Registration System |
| AD | Activity data |
| AFOLU | Agriculture, Forestry and Other Land Use |
| AWMS | Animal waste management systems |
| BCEF | Biomass conversion and expansion factor |
| BEF | Biomass expansion factor |
| BOD | Biochemical oxygen demand |
| BOF | Basic oxygen furnace |
| BOTAŞ | Petroleum Pipeline Company |
| BWD | Basic wood density |
| C | Carbon |
| $C_2F_6$ | Hexafluoroethane |
| $CaCO_3$ | Calcium carbonate |
| CAGR | Compound annual growth rate |
| $CaMg(CO_3)_2$ | Dolomite |
| CaO | Calcium oxide |
| CBCC | Coordination Board on Climate Change |
| CBCCAM | Coordination Board on Climate Change and Air Management |
| CF | Carbon fraction of dry matter |
| CF | Carbon fraction |
| $CF_4$ | Carbon tetrafluoride |
| CFCs | Chlorofluorocarbons |
| $CH_4$ | Methane |
| CITEPA | Technical Reference Center for Air Pollution and Climate Change |
| CKD | Cement kiln dust |
| CL-SL | Cropland converted to settlements |
| cm | Centimeter |

| | |
|---|---|
| CO | Carbon monoxide |
| $CO_2$ | Carbon dioxide |
| $CO_2$ eq. | Carbon dioxide equivalent |
| COD | Chemical oxygen demand |
| CORINAIR | Core Inventory of Air Emissions in Europe |
| CORINE | Coordinate Information on the Environment |
| CRF | Common Reporting Format |
| CS | Country specific |
| CSC | Carbon stock change |
| D | Default |
| DG | Directorate of General |
| dm | Dry matter content |
| DOC | Degradable organic carbon |
| DOM | Dead Organic Matter |
| DOCF | Fraction of degradable organic carbon |
| EAF | Electric arc furnace |
| EF | Emission factor |
| $EF_c$ | Baseline emission factor for continuously flooded fields without organic amendments |
| EHCIP | Environmental Heavy Cost Investment Planning |
| EMEP | European Monitoring and Evaluation Programme |
| ENVANIS | Inventory Statistical System for Forests |
| ERT | Expert Review Team |
| EU | European Union |
| F | Fraction of methane |
| FAO | Food and Agriculture Organization of the United Nations |
| FCF | Fossil carbon content |
| F-gases | Fluorinated gases |
| FOD | First Order Decay |
| $Frac_{GASF}$ | Fraction of synthetic fertiliser N that volatilises as $NH_3$ and $NO_x$ |
| $Frac_{GASMS}$ | Percent of managed manure nitrogen that volatilises as $NH_3$ and $NO_x$ in the manure management system S |
| $Frac_{GASM}$ | Fraction of applied organic N fertiliser materials and of urine and dung N deposited by grazing animals that volatilises as $NH_3$ and $NO_x$ |

| | |
|---|---|
| $Frac_{LEACH-(H)}$ | Fraction of all N added to/mineralised in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff |
| $Frac_{LEACHMS}$ | Percent of managed manure nitrogen losses due to runoff and leaching during solid and liquid storage of manure |
| $F_{comp}$ | Annual amount of total compost N applied to soils |
| $F_{sew}$ | Annual amount of total sewage N that is applied to soils |
| g | gram |
| GDF | General Directorate of Forestry |
| GDP | Gross Domestic Product |
| GE | Gross energy intake |
| GHG | Greenhouse gas |
| GIS | Geographical Information System |
| GJ | Gigajoule |
| GL-SL | Grasslands converted to settlement |
| GW | Gigawatt |
| GWh | Gigawatt hour |
| ha | Hectare |
| HAC | High activity clay |
| HFCs | Hydrofluorocarbons |
| HWP | Harvested wood product |
| ICP | International Cooperative Programme |
| IE | Included elsewhere |
| IEA | International Energy Agency |
| IEF | Implied emission factor |
| IFA | International Fertilizer Association |
| IPCC | Intergovernmental Panel on Climate Change |
| IPPU | Industrial processes and product use |
| IW | Industrial Waste |
| k | Methane generation rate constant |
| kha | Kilo hectare |
| KİSAD | Lime Producers Association |
| km | kilometer |
| kt | Kilo tonnes |
| ktoe | Kilo tonnes of oil equivalent |

| | |
|---|---|
| kW | Kilowatt |
| kWh | Kilowatt hour |
| L | Litter |
| LPG | Liquefied petroleum gas |
| LRS | LULUCF reporting system |
| LTO | Landing and take-off |
| LULUCF | Land Use, Land Use Change and Forestry |
| MAPEG | General Directorate of Mining and Petroleum Affairs |
| MC | Monte Carlo |
| MCF | Methane correction factor |
| ME | Main engine |
| MENR | Ministry of Energy and Natural Resources |
| $MgCO_3$ | Magnesium carbonate |
| MgO | Magnesium oxide |
| MJ | Megajoule |
| MMS | Manure Management Systems |
| MoAF | Ministry of Agriculture and Forestry |
| MoEF | Ministry of Environment and Forestry |
| MoEU | Ministry of Environment and Urbanization |
| MoT | Ministry of Trade |
| MoTI | Ministry of Transport and Infrastructure |
| MRV | Monitoring, Reporting, Verification |
| MS | Manure Management System Usage |
| $MSm^3$ | Million standard cubic meter |
| MSW | Municipal solid waste |
| Mt | Million tonnes |
| MW | Megawatt |
| N | Nitrogen |
| $N_2O$ | Nitrous oxide |
| NA | Not applicable |
| $Na_2CO_3$ | Sodium carbonate |
| NaCl | Sodium cloride |
| NCV | Net calorific value |

| | |
|---|---|
| NE | Not estimated |
| NES | EU Integrated Environmental Adaptation Strategy |
| Nex | Annual nitrogen excretion |
| $NH_3$ | Ammonia |
| NIR | National Inventory Report |
| NMVOC | Non-methane volatile organic compounds |
| NO | Not occurring |
| $NO_x$ | Nitrogen oxides |
| ODS | Ozone-depleting substances |
| ODU | Oxidised During Use |
| OHF | Open hearth furnace |
| OSP | Official Statistics Programme |
| OX | Oxidation factor |
| PFCs | Perfluorocarbons |
| PRODCOM | Industrial Production Statistics Survey |
| PS | Plant specific |
| QA/QC | Quality assurance and quality control |
| R | Root-to-shoot ratio |
| S | Soil |
| SEM | Ship Emission Model |
| $SF_6$ | Sulphur hexafluoride |
| SFOC | Specific Fuel Oil Consumption |
| $SF_p$ | Scaling factor regarding water regime before the cultivation period |
| $SF_w$ | Scaling factor regarding water regime during the cultivation period |
| $SO_2$ | Sulphur dioxide |
| $SO_x$ | Sulphur oxide |
| SOM | Soil Organic Matter |
| SWDS | Solid waste disposal sites |
| t | Tonnes |
| T | Degrees of treatment utilization |
| T1 | Tier 1 |
| T2 | Tier 2 |
| T3 | Tier 3 |

| | |
|---|---|
| TACCC | Transparency, accuracy, comparability, consistency, and completeness |
| TADPK | Tobacco and Alcohol Market Regulatory Authority |
| TCMA | Turkish Cement Manufacture Association |
| TEİAŞ | Turkish Electricity Transmission Company |
| TJ | Terajoule |
| TLA | Turkish Lime Association |
| TOBB | The Union of Chambers and Commodity Exchanges of Turkey |
| TOR | Terms of Reference |
| TOW | Total organics in wastewater |
| TPES | Total Primary Energy Supply |
| TRGM | General Directorate of Agricultural Reform |
| TTGV | Technology Development Foundation of Turkey |
| TUBITAK | Scientific and Technical Research Council of Turkey |
| TurkStat | Turkish Statistical Institute |
| TÜPRAŞ | Turkish Petroleum Refineries Co. |
| TWh | Terawatt hour |
| UNECE | United Nations Economic Commission for Europe |
| UNFCCC | United Nations Framework Convention on Climate Change |
| USD | United States dollar |
| Vol | Volume |
| WF | Waste fractions |
| WG | Working group |
| $Y_m$ | Methane conversion factor |
| yr | year |

# 1. INTRODUCTION

## 1.1. Background Information on GHG Inventories

The UNFCCC and the Kyoto Protocol were ratified by Turkey in 2004 and 2009 respectively. As an Annex I party to Convention, Turkey is required to develop annual inventories on emissions and removals of GHG not controlled by the Montreal Protocol using the IPCC Guidelines. National Greenhouse Gas Inventory of Turkey was set up in 2006. Inventory covers all emissions and removals sources described in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines). Emissions and removals have been estimated and reported in line with the 2006 IPCC Guidelines. The National GHG Inventory consists of the national inventory report (NIR) and the common reporting format (CRF) tables in accordance with the UNFCCC reporting guidelines (24/CP.19). Time series of emissions and removals from 1990 to latest inventory year are covered in the Common Reporting Format (CRF).

2006 IPCC Guidelines were provided for the following sectors:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture
- Land Use, Land Use Change and Forestry (LULUCF)
- Waste

The emission inventory includes direct GHGs as $CO_2$, $CH_4$, $N_2O$, HFCs, $SF_6$, PFCs, $NF_3$ and indirect gases as $NO_x$, NMVOC and CO, and $SO_2$ emissions originated from energy, IPPU, agriculture, and waste. The emissions and removals from LULUCF are also included in the inventory. Indirect $CO_2$ emissions that are a consequence of the activities of the reporting entity, but available at sources owned or controlled by another entity are not occur.

In this report, the national GHG emissions and removals from 1990 to 2018, emission and removal sources, emission factors (EFs), difference between reference and sectoral approach, emission trends, fluctuations, changes, uncertainty estimations and key source categories were evaluated in detail.

## 1.2. Institutional Arrangements

### 1.2.1. Institutional, Legal and Procedural Arrangements

The Turkish national inventory system is featured by centralized governance. Ministry of Environment and Urbanization (MoEU) is the National Focal Point of the UNFCCC, and is responsible for climate change and air pollution policies and measures. Turkey established the Coordination Board on Climate Change (CBCC) in 2001 with the Prime Ministerial Circular no.2001/2 in order to determine the policies, measures and activities to be pursued by Turkey on climate change. Under the chairmanship of Minister of Environment and Urbanization, this board is composed of high level representatives (Undersecretary and President) from Ministries related to foreign relations, finance, economy, energy, transport, industry, agriculture, forestry, health, education, TurkStat, and Non-Governmental Organisations (NGOs) from business sector. The CBCC was restructured in 2013, and renamed as Coordination Board on Climate Change and Air Management (CBCCAM). The CBCCAM, a public body created by Prime Minister Circular 2013/11, is competent for taking decisions and measures related to climate change and air management.

Coordination Board on Climate Change and Air Management Decisions is the first legal means for national inventory system.

Under the Coordination Board currently there are seven working groups (WGs):

- GHG Mitigation WG
- Climate Change Adverse Effects and Adaptation WG
- GHG Emission Inventory WG
- Finance WG
- Technology Development and Transfer WG
- Education, Capacity Building WG
- Air Management WG

The national GHG inventory is prepared under the auspices of the "GHG Emission Inventory Working Group" which was established in 2001 by the former CBCC. TurkStat was formally appointed as single national responsible authority to coordinate and implement national inventory activities from planning to management by Decision 2009/1 of the CBCC in 2009. TurkStat is also in charge of annual inventory submission to the UNFCCC Secretariat and of responding to the ERT recommendations.

Also, the legal basis of the national inventory system is currently provided by the Statistics Law of Turkey through the Official Statistics Programme (OSP). The OSP is based on the Statistics Law of Turkey No.

5429 and was first prepared in 2007 for a 5-year-period and updated every 5 years. OSP identifies the basic principles and standards dealing with the production and dissemination of official statistics and produce reliable, timely, transparent and impartial data required at national and international level. For all kind of official statistics, the responsible and related institutions are defined, data compilation methodology and the publication periodicity/schedule of official statistics are specified. TurkStat is the responsible institution for the compilation of the national GHG inventory through the OSP and coordinates the activities of the GHG emission inventory working group established in the scope of OSP with the same composition as the GHG emission inventory working group under CBCCAM.

The GHG national inventory is compiled by GHG Emission Inventory working group under the coordination of TurkStat.

The institutions included in the working group are:

- Turkish Statistical Institute (TurkStat),
- Ministry of Energy and Natural Resources (MENR),
- Ministry of Transport and Infrastructure (MoTI),
- Ministry of Environment and Urbanization (MoEU),
- Ministry of Agriculture and Forestry (MoAF).

The national inventory arrangements are designed and operated to ensure the TACCC quality objectives and timeliness of the national GHG inventories. The quality requirements are fulfilled by implementing consistently inventory quality management procedures.

Responsibilities of the institutions involved in the national GHG inventory are shown in Table 1.1.

**Table 1.1 Institutions by responsiblities for national GHG inventory**

| Sector | CRF category | Collection of AD | Selection of methods and EFs | GHG emission calculations | Filling in CRF tables and preparing NIR | Quality control |
|---|---|---|---|---|---|---|
| Energy | 1 –Energy (Excluding 1.A.1.a – Public electricity and heat production, and 1.A.3 – Transport) | MENR, TurkStat | TurkStat | TurkStat | TurkStat | TurkStat |
| | 1.A.1.a – Public electricity and heat production | MENR | MENR | MENR | MENR | MENR |
| | 1.A.3 – Transport | MoTI, TurkStat | MoTI | MoTI | MoTI | MoTI |
| Industrial processes and product use | 2 – IPPU (except F-gases) | TurkStat | TurkStat | TurkStat | TurkStat | TurkStat |
| | F-gases | MoEU | MoEU | MoEU | MoEU | MoEU |
| Agriculture | 3 – Agriculture | TurkStat | TurkStat | TurkStat | TurkStat | TurkStat |
| Land use, land-use change and forestry | 4 – LULUCF | MoAF | MoAF | MoAF | MoAF | MoAF |
| Waste | 5 – Waste | TurkStat | TurkStat | TurkStat | TurkStat | TurkStat |
| **Cross cutting issues** | | | | | | |
| Key category analysis | TurkStat | | | | | |
| Uncertainty analysis | TurkStat | | | | | |

**National Inventory Official Consideration and Approval;**

The national GHG inventory is subject to an official consideration and approval procedure before its submission to the UNFCCC. The national inventory is subject to a two-step official consideration and approval process. The final version of the NIR and CRF tables is first approved by the TurkStat Presidency and published in the official TurkStat press release. The publishing schedule for the press release of Greenhouse Gas Emissions Statistics can be found on National Data Release Calendar (*http://www.turkstat.gov.tr/ingtakvim/tkvim.zul#tb1*). Subsequently, The MoEU as National Focal Point to the UNFCCC provides final checks and approval of the CRF tables via CRF web application tool as a final step prior to its submission to the UNFCCC.

TurkStat, as the Single National Entity, is responsible from official inventory submission to UNFCCC, and also responsible for responding to the UNFCCC expert review team (ERT) recommendations on national

inventory improvement and ensuring they are incorporated in the current and following NIR(s) in the broader context of its continuous improvement.

### 1.2.2. Overview of Inventory Planning, Preparation and Management

The inventory planning system of Turkey is conducted in line with quality assurance and quality control (QA/QC) plan. Planning stage is under the responsibility of GHG Inventory WG. Planning activities include data collection and processing, selection of EF estimation methodology, compilation of CRF and NIR, UNFCCC expert review team (ERT) recommendations, documentation and archiving, verification through time series consistency and cross checks, reporting and publication process.

Every year in the autumn, about October, WG meeting is organized to agree on a work plan and calendar for the following submission.

Information required for the inventory are mostly covered by OSP. Distribution of work for data gathering, processing and estimation of emissions are shown in Table 1.1. Emissions originating from energy, industrial processes and product use, agriculture and waste, and emissions and removals from LULUCF are calculated at national level annually by using recommended approaches in 2006 IPCC Guidelines. Fuel combustion emissions other than electricity generation and transport are calculated by TurkStat via using the energy balance tables of the Ministry of Energy and Natural Resources. Emissions from industrial processes (excluding F-gases), agriculture, waste and fugitive emissions from coal mining, oil and gas systems are also calculated by TurkStat. The emissions originating from public electricity and heat production are calculated on the basis of plant level data by the Ministry of Energy and Natural Resources; the emissions originating from transportation are calculated by the Ministry of Transport and Infrastructure. The fluorinated gases are calculated by the Ministry of Environment and Urbanization. Emissions and removals from land use, land-use change and forestry are estimated by the Ministry of Agriculture and Forestry.

Every sector expert that performs the emission estimation has responsible for the data entry to CRF reporter, and prepare related section or sub-section of NIR. TurkStat compiles and make key source and uncertainty analysis and do final quality checks, and submits the national GHG inventory to the UNFCCC Secretariat.

TurkStat is also responsible from archiving the GHG inventory. Central archiving is carried out by TurkStat. EFs, AD, calculation sheets, CRF and NIR outputs, etc. regarding the emission inventory are archived on TurkStat main server. All inventory related documents are also archived by the in line Ministries for the CRF categories under their responsibilities.

### 1.2.3. Quality Assurance, Quality Control and Verification

QA/QC and verification procedures are an integral and indispensable part of the national GHG inventory of Turkey. The quality of the national inventory system is ensured by the QA/QC system, through the QA/QC plan adopted by the CBCCAM decision in 2014 and revised and updated in 2017. The QA/QC plan introduces the structure and purpose of the QA/QC system, endorse the quality objectives. The main objective of the QA/QC plan is to ensure that the national GHG inventory is prepared in accordance with the quality objectives: transparency, accuracy, comparability, consistency, completeness (TACCC) as defined in UNFCCC reporting guidelines (24/CP.19). Turkey also considers three additional quality objectives as improvement, sustainability and timeliness.

Improvement: Processes ensure that the inventory represents the best possible estimates of GHG emissions and sinks for all categories, given the current state of scientific knowledge, data availability and national resources, taking into account information gained and lessons learned from reporting and review in the latest GHG inventory cycle.

Sustainability: Processes ensure the continuity of the GHG inventory system through institutional memory by establishing a documentation/archiving system and methodological manuals, as well as a training package for newcomers and periodic refreshment trainings for existing inventory experts.

Timeliness: All of the QA/QC procedures are developed with a view to enabling the timely submission of the NIR and the accompanying CRF tables to the UNFCCC by 15 April each year. In addition, inventory inputs, references and materials should be transparently documented and accessible, to enable timely responses to external requests for information, including during formal and informal inventory review processes.

Together with verification, the implementation of QA/QC procedures are considered integral part of national inventory preparation and play a pivotal role not only to achieve the quality objectives but also for continuous reassessing and improving the national inventory where needed.

TurkStat is the designated body for overall implementation of the QA/QC system and for ensuring coordination of the QA/QC activities.

Quality Control (QC) is a system of routine technical activities to assess and maintain the quality of the inventory as it is being compiled. It is performed by personnel compiling the inventory. QC activities include general methods such as accuracy checks on data acquisition and calculations, and the use of approved standardised procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting. QC activities also include technical reviews of categories, activity data, emission factors, other estimation parameters, and methods.

The data used in the preparation of the national GHG inventory for the agriculture, waste, and IPPU sectors are obtained from agricultural statistics, industrial production statistics, and waste statistics databases of TurkStat. TurkStat is producing all its statistics according to the European Statistics Code of Practice which covers a common quality framework in the European Statistical System. Therefore, high quality data are used in the inventory.

In Turkey, in addition to data available from national statistics, some plant-level data are used to estimate input parameters for emissions calculations. No QC procedures are available for data providers at the moment. If data are official statistics from TurkStat, then it is ensured that the statistics are produced in line with the EU code of practice. However, if the data source is not from the official statistics QC can be performed by the inventory team.

In detail, with regard to QC the following rules and steps apply:

- Each institution involved in national inventory development is responsible for its own QC general and category specific activities,
- Both general and category specific QC activities are carried out by sectorial QC experts within the Institutions, using the ad hoc check lists attached in Annex II (general QC) and Annex III (category specific) of the QA/QC plan,
- Check lists are filled in by sectorial QC experts for the CRF categories under their responsibility and sent to TurkStat with an official letter,
- TurkStat files the letters,
- QC sectorial experts make the corrections needs emerging from the QC activities,
- TurkStat prepares a summary of the QC results,
- An improvement plan is prepared by the national inventory team under TurkStat coordination.

The QA/QC plan (approved in 2017) including above mentioned annexes can be found at *https://biruni.tuik.gov.tr/yayin/views/visitorPages/english/index.zul*.

Criteria for assessing achievement of quality objectives is given below in Table 1.2.

**Table 1.2 Criteria for assessing achievement of quality objectives**

| Data quality objective | Criteria for assessing achievement of quality objective |
|---|---|
| Accuracy | • Emissions are neither overestimated or underestimated as far as can be judged,<br>• Uncertainty estimates are provided for AD, EF, and emissions in each category for the base year, the most recent year, and the trend. |
| Comparability | • Turkey applies methods from the 2006 IPCC Guidelines, in accordance with the significance of the category in the country (e.g., whether or not it is a key category) and national circumstances. |
| Completeness | • All categories for which methods are provided in the 2006 IPCC Guidelines are included in the national GHG inventory,<br>• Emissions estimates cover the entire geographic area of Turkey,<br>• Emissions values or notation keys are provided for each cell in the CRF tables,<br>• If despite the best efforts, emissions for a category for which methods are provided in the 2006 IPCC Guidelines cannot be provided, the situation regarding the lack of reporting is transparently described in the NIR. |
| Consistency | • Turkey has applied the same method across the time series for a given category and can explain the trends observed in the time series,<br>• If the same method is not used for the entire time series in a category, Turkey can explain (and documents in the NIR) why the selected method(s) ensure time series consistency. |
| Improvement | • The national inventory improvement plan is updated with the recommendations and encouragements from the relevant review processes (e.g. UNFCCC) and QA/QC summary reports,<br>• Turkey implements findings from review processes where feasible. |
| Sustainability | • All inventory related documents (NIR, data sheets, EFs, CRF tables) are archived annually,<br>• All information on choice of methodology, EFs and parameters, assumptions used, are documented and updated as needed,<br>• All methodological manuals are prepared and updated as needed. |

**Table 1.2 Criteria for assessing achievement of quality objectives (cont'd)**

| Data quality objective | Criteria for assessing achievement of quality objective |
|---|---|
| Timeliness | • Inventory is submitted to the UNFCCC by 15 April annually,<br>• Turkey is able to timely respond to questions from the UNFCCC ERT. |
| Transparency | • Information necessary to reproduce the emissions estimates is either provided in the annual submission or referenced therein,<br>• The elements required to be included in the NIR per paragraph 50 of the annex to decision 24/CP.19 are included, in particular clear descriptions of:<br>• All methods selected and models used<br>• Values and sources of AD, EFs and other parameters<br>• Relevant information on key categories and uncertainties<br>• Recalculations are clearly explained<br>• Completeness of the inventory<br>• Changes in response to the review process<br>• Description of the national inventory arrangements. |

### General QC Procedures

General QC procedures include generic quality checks related to calculations; data processing, completeness, and documentation that are applicable to all inventory source and sink categories. General QC procedures are applied routinely to all categories by sector experts using the check lists attached in Annex II of the QA/QC plan during the acquisition of data and the emissions calculation procedures and during the compilation of NIR and the CRF tables.

Each sector expert should fill and sign the check list that the necessary QC checks were undertaken. Each sector expert should carry out immediate corrections of the input data/emissions calculations where errors are found. If an issue cannot be resolved during the current inventory submission, the sector experts should include an explanation for aspects still posing problems along with a recommendation(s) for future work on these issues. Such issues may then be incorporated into the inventory improvement plan. A copy of the completed checklist is sent to TurkStat and is archived in TurkStat.

The types of activities and procedures undertaken by sectoral experts include, but are not limited to:

- Cross-check descriptions of AD, EFs and other estimation parameters with information on categories and ensure that these are properly recorded and archived. This step includes ensuring that definitions and assumptions for the underlying AD match the definitions of categories used in the GHG inventory. In some cases, data collected from national statistics may have different coverage than that required for inventory preparation,
- Ensure that the time series of input EF, AD and other parameters are justifiable, and that any outliers can be explained by national circumstances,
- Ensure that proper bibliographic information is available and documented in the archives for all input parameters,
- Cross-check a sample of input data to ensure that there are no transcription errors,
- Where AD or EF data are obtained from plant operators Turkey plant level data are compared with previous data and related indicators (kwh/TJ, kwh/$m^3$ $CH_4$) and published national data,
- Check that units are properly labeled for all input data and, for a subset of parameters, correctly transcribed and applied in the emissions calculation spreadsheets,
- Where a parameter is based on expert judgement, is identifying information for the expert (including their affiliation and any relevant expertise) documented and archived,
- Has the sector expert identified where recalculations of previous input data have been undertaken? Qualitative reasons for, and the quantitative impacts of, these recalculations should be documented in the NIR.

### Category-Specific QC Procedures

Category-specific QC procedures complement general inventory QC procedures and are directed at specific types of data used in calculating GHG emissions for individual source or sink categories. These procedures require knowledge of the specific category, the types of data available and the parameters associated with emissions or removals, and are performed in addition to the general QC checks. Category specific QC procedures are also applied by sector experts using the check lists attached in Annex III of the QA/QC plan.

Each sector expert should fill and sign the check list that the necessary QC checks were undertaken, and summarizes the unsolved issues. A copy of the completed checklist is sent to TurkStat and is archived in TurkStat.

The types of activities and procedures undertaken by sectoral experts include, but are not limited to:

- Assumptions for AD, EFs and other parameters are compared with IPCC values and significant differences are noted,
- National and regional comparability and trends of AD, EF or other assumptions are checked against alternative data sources,
- Conduct of an in-depth review of the background data used to develop a country-specific EF, including the adequacy of any plant-level measurement programmes upon which the country-specific EF was developed. Such an in-depth review may also involve an assessment of any national literature used in support of the development of the country-specific factor,
- Evaluate any peer reviewed literature evaluating national or plant level statistics and suitability for the use in the GHG inventory,
- Hand-checking the accuracy of random calculations,
- To the extent possible, are the only hardwired data in the spreadsheets the basic input data (e.g., AD, EFs and assumptions) with all other spreadsheets using spreadsheet tools to link and calculate emissions,
- Reviewing the time series consistency of emissions calculations for any outliers and compare whether the values are within the minimum – maximum interval of other Parties,
- Checking a random sampling of conversion factors to ensure proper calculation from input data to emissions calculations,
- Is the IEF calculated reasonable compared with the previous annual submission and with the 2006 IPCC Guidelines,
- Is the time series of the IEF reasonable- are any large changes explainable,
- Checking that confidentiality is assured by Statistics Law of Turkey,
- Are emissions estimates (or notation keys) available for all years of the time series for mandatory categories, from 1990 to the year "t-2" and do the emissions estimates cover all sources in the category (as determined by cross checks using other publicly available information),
- Identify parameters (e.g., AD, constants) that are common to multiple categories and confirm that there is consistency in the values used for these parameters in the emission/removal calculations. This is particularly important when reviewing calculations for the agriculture and LULUCF sector, as well as when reviewing input data between the reference and the sectoral approach.

### QC Procedures Applied to Compiled NIR and CRF Tables

TurkStat undertakes further quality checks on compiled CRF and NIR. The types of activities and procedures undertaken include:

***CRF tables***

- Completeness of all cells in the CRF tables with either a value or a notation key,
- Appropriateness of notation keys used ,
- Where the notation key "NE" or "IE" is used, whether an appropriate description is included in CRF table 9 to indicate why data are not reported (in the case of "NE") or where data are reported (in case of "IE"),
- Where emissions data are reported as confidential, it is ensured that emissions are included elsewhere (properly aggregated to assure confidentiality of information) and, therefore, included in national totals,
- Check whether appropriate tiers are used for key categories, in accordance with the decision trees in the 2006 IPCC Guidelines. Where appropriate tiers are not used, is an appropriate discussion included in the NIR to document the national circumstances surrounding the methodological choice?
- Review of documentation boxes of the CRF tables for appropriate content and language.

***NIR***

- All tables, figures and text have been updated to reflected the latest annual data,
- Does the description of trends match the trends seen taking into account the latest year, and any recalculations of earlier years' data,
- Check the introductory chapters and annex to make sure that the data contained therein match the latest inventory data,
- Have all recalculations identified been documented in the NIR and the impacts of the recalculation described?
- Assessment of completeness of the category described in the NIR,
- Consistent use of units in the NIR and the CRF tables,
- A general check of the NIR should be done for consistency,
- All references should be included in the NIR and the same reference should be referred to consistently across chapters,
- Ensure that all web links are active and direct the readers to the appropriate content.
- After inventory submission to UNFCCC,
- Ensures that all inventory related materials were archived by inventory sectoral experts.

In the previous submission, emissions from energy, IPPU and agriculture sectors were calculated on SAS and it was double checked by the calculations on the Excel sheets by two different experts and any findings were corrected.

### Quality Assurance

Quality Assurance (QA) is a planned system of review procedures conducted by personnel not directly involved in the inventory compilation/development process. Reviews, preferably by independent third parties, are performed upon a completed inventory following the implementation of QC procedures. Reviews verify that measurable objectives (data quality objectives) were 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.

Due to the comprehensive and costly nature of QA activities, these procedures are only applied for selected categories and selected years, and generally only for key categories.

Turkey's approach to QA is to prioritize:

- The categories that have high uncertainty,
- The categories that are recalculated,
- The categories that were included in the improvement plan.

In Turkey, QA activities are conducted by experts in the scope of European Union (EU) funded Projects. For this purpose, first, in the scope of EU funded Upgrading the Statistical System of Turkey project, external experts from EU countries were invited to review Turkish GHG Inventory for all categories before in-country review in 2014. Some improvements has been achieved based on review outputs of the EU inventory experts.

Also the EU funded Project named as Technical Assistance for Support to Mechanisms for Monitoring Turkey's GHG Emissions, project period was January 2015 - April 2017, aimed to strengthen existing capacities in Turkey and assist the country to:

- Fully implement a monitoring mechanism of GHG emissions in Turkey, in line with the EU Monitoring Mechanism Regulation 525/2013 repealing Decision 280/2004/EC, and
- Better fulfill its reporting requirements to the UNFCCC, including national GHG inventories, National Communications and Biennial Reports.

Under the technical assistances of experts from project team national GHG inventory was reviewed and improved through workshops, mentor style trainings, and meetings organized.

For the period 2017-2019, TurkStat was responsible for implementing an investment project with the objective of improving the GHG Inventory. Under this project, a QA work was conducted for the agriculture sector in 2017. Likewise, another QA work was conducted for the energy sector in 2018.

"Technical Assistance for New Era for Statistics Programme" which is co-funded by the European Union and the Republic of Turkey, has been started since March 2019. Within the scope of this project, under sub-activity "National Greenhouse Gas Inventory", the experts from CITEPA – Technical Reference Center for Air Pollution and Climate Change – provided QA works for the energy, IPPU, agriculture and waste sectors of the Turkish GHG Inventory between December 2019 and February 2020.

In addition, Turkey's GHG inventory submission is subject to review by an international team of experts on an annual basis in accordance with decision 13/CP.20. During the review week, Turkey ensures that all institutions, organizations and responsible sector experts are available to provide necessary information and supporting documentation to the review team in a timely manner. The Expert Review Team (ERT) then develops an annual review report based on the findings of the review. These annual review reports are considered as supplementary to the QA procedures undertaken by experts in Turkey. Findings in the annual review reports are considered feedback for improvement of the GHG inventory, and as such are included in Turkey's inventory improvement plan. Improvements regarding the recommendations identified by the expert review team in the most recent review are generally summarized in chapter 10 (Table 10.2-10.4) of the current submission. However, the comments/actions for ERT recommendations could not be provided in the above-mentioned tables of this report, since the "Report on the individual review of the inventory submission of Turkey submitted in 2019" has not been finalized yet.

### Verification

Verification activities typically include comparing inventory estimates with independent estimates to either confirm the reasonableness of the inventory estimates or identify major discrepancies. Verification activities may be directed at specific categories or the inventory as a whole, and their application will depend on the availability of independent estimation methodologies that can be used for comparison.

Each Institution involved in national inventory development is responsible for its own verification activities. Sectorial experts within the Institution carry out the activities.

In Turkey, some level of verification happens on an annual basis, as Turkey estimates and reports $CO_2$ emissions from fossil fuel combustion based on both the reference approach and the sectoral approach. Differences in the emissions estimated using these two approaches are described in the NIR.

The national GHG emissions in the energy sector are estimated by using fuel consumption data taken from energy balance tables produced by the MENR. These data are compared with International Energy Agency (IEA) data. Inconsistencies between two data sets are identified and the reasons for these inconsistencies are investigated.

Also lower tier IPCC methods applied for comparison in especially energy sector. Emissions calculated and reported on the basis of higher tiers (Tier 2 or Tier 3) are compared with emissions calculated by Tier 1 method.

In current situation, in Turkey, there is no other emission calculation to compare whole inventory or sub-sectors. However, Regulation on the Monitoring of Greenhouse Gases has been came into force since 2012. In the scope of that Regulation, companies report their verified GHG emissions to the MoEU from 2017 onwards. GHG emissions from most of the IPCC categories are compared with those emissions reported under the MRV Regulation.

### Documentation and Archiving

Regarding, documentation and archiving, all sectoral experts archive all inputs used in the inventory process, outputs, selected EFs, work files, e-mails and official letters on their computer, on a network server with restricted access or on an external drive as softcopy or as hardcopy. Archiving is done according to Regulation on State Archive Services. Sectoral experts are responsible for archiving in their own institutions.

Central archiving is carried out by TurkStat. EFs, AD, calculation tables, CRF and NIR outputs, etc. regarding the emission inventory are stored on TurkStat main server. Sectoral experts transfer EFs, AD and calculation tables used in emission calculations to TurkStat within 6 weeks following the date of submission of the Annual Inventory to UNFCCC Secretariat.

## 1.3. Brief Description of the Process of Inventory Preparation

Turkey's inventory preparation starts with inventory planning which covers recalculations, methodological improvements and refinements according to quality management and improvement plans based on learning from previous inventory cycle, UNFCCC review reports and collaborations with government institutions. Reviewing the calculation methods are finalized by the end of November and the data collection process is completed by the end of December. After that, in January and February, emissions are estimated. QC checks and estimates are done by experts in mid-February. NIR text and CRF tables are then prepared according to UNFCCC guidelines. The inventory process also involves key category assessment, recalculations, uncertainty assessment, documentation and archiving. Main steps

in the annual inventory preparation process are summarized below in Table 1.3 with starting and ending dates.

**Table 1.3 Time schedule for preparation of the "t-2" annual inventory submission**

| | Activity | Start date | Deadline |
|---|---|---|---|
| 1. | Inventory planning by GHG Inventory WG (Creating Inventory Improvement Plan, recalculation, etc.) | 01.05.XX-1 | 30.09.XX-1 |
| 2 | Reviewing emission calculation methods, EFs, AD sources, etc. by GHG Inventory WG | 15.09.XX-1 | 30.11.XX-1 |
| 3. | Collection of AD and QC of the data by the institutions involved | 01.11.XX-1 | 31.12.XX-1 |
| 4. | Calculation of all emissions from electricity production, transportation, F-gas, emissions and removal from LULUCF by the related Institutions, and transfer to TurkStat. | 15.12.XX-1 | 15.02.XX |
| 5. | Calculation of emissions under the responsibility of TurkStat | 15.12.XX-1 | 15.02.XX |
| 6. | QC of the calculated emissions | 15.12.XX-1 | 15.02.XX |
| 7. | AD and emission entry to CRF reporter by sectoral experts | 15.02.XX | 15.03.XX |
| 8. | Performing key source, trend and uncertainty analysis by TurkStat | 15.02.XX | 15.03.XX |
| 9. | Preparation of Emission Inventory Report by the institutions involved and compilation by TurkStat | 15.02.XX | 31.03.XX |
| 10. | Approval of National GHG Emission Inventory by Inventory Focal Point | 01.04.XX | 10.04.XX |
| 11. | Release of the National GHG Inventory as press release on TurkStat webpage. | 01.04.XX | 15.04.XX |
| 12. | Reporting of Inventory to UNFCCC Secretariat by TurkStat | 10.04.XX | 15.04.XX |
| 13. | Documentation and archiving processes | 15.04.XX | 30.05.XX |

## 1.4. Brief General Description of Methodologies and Data Sources

The National GHGs are calculated by using 2006 IPCC Guidelines. $CO_2$ emissions from energy are calculated by using Tier 2 (T2) approach except for biomass and other fossil fuels. $CH_4$ and $N_2O$ emissions from all subcategories of energy excepting 1A1a category are calculated by using Tier 1 (T1). Technology specific EFs are used for $CH_4$ and $N_2O$ emissions from 1A1a category. For the emissions from coke production, due to plant specific data are gathered, Tier 3 (T3) methodology are used.

For industrial process and product use, T2 methodology was used for the $CO_2$ emissions from cement production, ammonia ($NH_3$) production. T3 methodology is used for $CO_2$ emissions from iron and steel production and GHG emissions from aluminum production. For the emissions from rest of the IPPU categories, T1 methodology was used.

For agriculture sector; T2 is used for emissions from enteric fermentation. For the other categories T1 methodology was used.

For LULUCF; T2 methodology was used for the emissions/removals from forestland, cropland, grassland and emissions from harvested wood product (HWP). For the other categories T1 methodology was used.

In waste sector; for the $CO_2$ emissions from open burning of waste, which is only $CO_2$ emission source for waste sector is calculated by using T2 method. For $CH_4$ emissions from solid waste disposal, T2 methodology was used while T1 was used for the rest of $CH_4$ emission source category. For $N_2O$ emissions, T1 methodology was used for all categories. All tier methodologies are summarized on sector basis in below Table 1.4.

**Table 1.4 Summary for methods and emission factors used, 2018**

| Greenhouse Gas Source and Sink Categories | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| **1. Energy** | T1,T2,T3 | CS,D,PS | T1,T2,T3 | D,PS | T1,T2,T3 | D,PS |
| A. Fuel combustion | T1,T2,T3 | CS,D,PS | T1,T2,T3 | D,PS | T1,T2,T3 | D,PS |
| 1. Energy industries | T2,T3 | CS,D,PS | T2,T3 | D,PS | T2,T3 | D,PS |
| 2. Manufacturing industries and construction | T1,T2 | CS,D | T1 | D | T1 | D |
| 3. Transport | T1,T2 | CS,D | T1,T2 | D | T1,T2 | D |
| 4. Other sectors | T1,T2 | CS,D | T1 | D | T1 | D |
| B. Fugitive emissions from fuels | T1 | D | T1 | D | T1 | D |
| 1. Solid fuels | NE | NE | T1 | D | NE | NE |
| 2. Oil and natural gas | T1 | D | T1 | D | T1 | D |
| C. $CO_2$ transport and storage | T1 | D | | | | |
| **2. Industrial processes** | T1,T2,T3 | CS,D | T1 | D | T1 | D |
| A. Mineral industry | T1,T2 | CS,D | | | | |
| B. Chemical industry | T1,T2 | CS,D | NE | NE | T1 | D |
| C. Metal industry | T1,T2,T3 | CS,D | T1 | D | NE | NE |
| D. Non-energy products from fuels and solvent use | T1 | D | NE | NE | NE | NE |
| E. Electronic industry | | | | | | |
| F. Product uses as ODS substitutes | | | | | | |
| G. Other product manufacture and use | NA | NA | NA | NA | NA | NA |
| H. Other | NA | NA | NA | NA | NA | NA |
| **3. Agriculture** | T1 | D | T1,T2 | CS,D | T1 | D |
| A. Enteric fermentation | | | T1,T2 | CS,D | | |
| B. Manure management | | | T1 | D | T1 | D |
| C. Rice cultivation | | | T1 | D | | |
| D. Agricultural soils | | | | | T1 | D |
| E. Prescribed burning of savannas | | | NO | NO | NO | NO |
| F. Field burning of agricultural residues | | | T1 | D | T1 | D |
| G. Liming | NE | NE | | | | |
| H. Urea application | T1 | D | | | | |
| I. Other carbon-containing fertilizers | NO | NO | | | | |
| J. Other | NO | NO | NO | NO | NO | NO |
| **4. Land use, land-use change and forestry** | T1,T2 | CS,D | T1 | D | T1 | D |
| A. Forest land | T2 | CS,D | T1 | D | T1 | D |
| B. Cropland | T1,T2 | CS,D | NE | NE | T1 | D |
| C. Grassland | T1,T2 | CS,D | NE | NE | T1 | D |
| D. Wetlands | T1,T2 | CS,D | NE | NE | T1 | D |
| E. Settlements | T1 | D | NE | NE | NE | NE |
| F. Other land | T1 | D | NO | NO | NO | NO |
| G. Harvested wood products | T2 | CS,D | | | | |
| H. Other | NO | NO | NO | NO | NO | NO |
| **5. Waste** | T2 | CS,D | T1,T2 | CS,D | T1 | D |
| A. Solid waste disposal | NA | NA | T2 | CS,D | | |
| B. Biological treatment of solid waste | | | T1 | D | T1 | D |
| C. Incineration and open burning of waste | T2 | CS,D | T1 | D | T1 | D |
| D. Waste water treatment and discharge | | | T2 | CS | T1 | D |

Table 1.5 provides an overview for inventory data sources by sectors;

**Table 1.5 Activity data sources for GHG inventory**

| Sector | Category | Activity data source |
|---|---|---|
| Energy | Energy – 1 (excluding 1.A.1 – Energy industry and 1.A.3 – Transportation) | MENR Energy balance sheet-sectoral fuel consumption data (for sectoral approach) and fuel supply data (for reference approach) |
| | | Directorate of Energy Efficiency and Environment and PETKIM - waste incineration data |
| | Public electricity and heat production – 1.A.1.a | MENR - Facility base electricity and heat production statistics |
| | Petroleum Refining– 1.A.1.b | TÜPRAŞ-fuel consumption data |
| | Manufacture of solid fuels and other energy industries– 1.A.1.c | Integrated iron and steel plants- fuel consumption for coke production |
| | Transportation – 1.A.3 | TurkStat-road vehicle fleet and vehicle-km travelled, MENR, MAPEG, Petroleum Pipeline Corporation - fuel consumption by transport mode |
| | | MoTI/DG of State Airports Authority - air traffic data |
| Industrial Process and Product Use | 2.A.1.Cement | Turkish Cement Manufacturer's Association - production and EF |
| | 2.A.2. Lime | Turkish Lime Association, Steel plants - production |
| | 2.A.3 Glass | Producers- glass production and parameters |
| | 2.A.4 Other process uses of carbonates | Turkish Ceramics Federation, producers and TurkStat-production, raw material consumption |
| | 2.B.1. Ammonia Prod. | Producers- production and fuel consumption |
| | 2.B.2 Nitric Acid Prod. | Producers- production and technology |
| | 2.B.5. Carbide Prod. | Producers- production and raw material |
| | 2.B.7. Soda ash prod. | Producers- production and raw material |
| | 2.B.8. Petrochemical and carbon black prod. | Producers- production |
| | 2.C.2. Iron and Steel Prod. | Producers- production and other parameters |
| | 2.C.2. Ferroalloy prod. | TurkStat - production |
| | 2.C.3 Aluminium Prod. | Plant - production and other parameters |
| | 2.C.5. Lead Prod. | TurkStat- production |
| | 2.C.6. Zinc Prod. | Producers- production |
| | 2.D.1. Lubricant Use | MENR- consumption |
| | 2.D.2. Paraffin wax use | MENR- consumption |
| | 2.E. Electronic industry | TurkStat - trade statistics |
| | 2.F. Product uses as substitutes for ODS | Ministry of Trade (MoT) - trade statistics |
| | 2.G.1. Electrical equipment | MoT - trade statistics - Turkish Electricity Transmission Corporation (TEİAŞ) |

**Table 1.5 Activity data sources for GHG inventory (cont'd.)**

| Sector | Category | Activity data source |
|---|---|---|
| Agriculture | Agriculture – 3 | TurkStat -<br>Livestock population<br>Crop production data<br>Waste disposal and treatment statistics<br><br>General Directorate of Meteorology - Temperature data<br><br>MoAF- Inorganic N Fertilizers application data, urea application data |
| Land Use, Land Use Change and Forestry | LULUCF - 4 | MoAF (General Directorate of Forestry) -<br>Landsat Satellite Images<br>Copernicus HRL for Forest (Sentinel)<br>The ENVANIS (Inventory Statistical System for Forests)<br>The annual commercial cutting and fuel wood data<br>The annual forest fire information (area)<br>The annual illegal cutting and wood gathering information<br><br>MoAF (General Directorate of Agricultural Reform) -<br>Landsat Satellite Images<br>CORINE land use maps<br>LPIS<br><br>General Directorate of State Hydraulic Works - the data of dam constructions |
| Waste | Waste – 5 | TurkStat -<br>Waste disposal and treatment statistics<br>Wastewater discharge and treatment statistics<br>GDP<br>Population and population projections<br><br>MoEU, TurkStat - waste composition data<br><br>Composting plants - amount of composted waste<br><br>Methane recovery facilities - amount of methane recovered from landfills and wastewater treatment plants |

## 1.5. Brief Description of Key Source Categories

The 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) recommend as good practice the identification of key categories of emissions and removals. The intent is to help inventory agencies prioritize their efforts to improve overall estimates. A key category is defined as "one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of GHG in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions and removals" (2006 IPCC Guidelines); this term is used in reference to both source and sink categories.

For the 1990-2018 GHG inventory, level and trend key category assessments were performed according to the recommended IPCC approach found in Volume 1, Section 4.3.1, of the 2006 IPCC Guidelines. The details of key category analysis are given in Annex 1.

Based on the key category with and without LULUCF, the followings are determined as key source in 2018.

**Table 1.6 Key categories for GHG inventory, 2018**

| Key Categories of Emissions and Removals | Gas | Criteria used for key source identification | | Key category exc. LULUCF | Key category inc. LULUCF |
|---|---|---|---|---|---|
| | | L | T | | |
| 1.A.1 Fuel combustion - Energy Industries - Liquid Fuels | $CO_2$ | X | X | X | X |
| 1.A.1 Fuel combustion - Energy Industries - Solid Fuels | $CO_2$ | X | X | X | X |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | $CO_2$ | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | $CO_2$ | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels | $CO_2$ | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | $CO_2$ | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels | $CO_2$ | | X | X | |
| 1.A.3.a Domestic Aviation | $CO_2$ | X | | X | X |
| 1.A.3.b Road Transportation | $CO_2$ | X | X | X | X |
| 1.A.4 Other Sectors - Liquid Fuels | $CO_2$ | X | X | X | X |
| 1.A.4 Other Sectors - Solid Fuels | $CO_2$ | X | X | X | X |
| 1.A.4 Other Sectors - Gaseous Fuels | $CO_2$ | X | X | X | X |
| 1.A.4 Other Sectors - Biomass | $CH_4$ | | X | X | X |
| 1.B.1 Fugitive emissions from Solid Fuels | $CH_4$ | X | X | X | X |
| 2.A.1 Cement Production | $CO_2$ | X | X | X | X |
| 2.A.2 Lime Production | $CO_2$ | X | X | X | X |
| 2.A.4 Other Process Uses of Carbonates | $CO_2$ | X | X | X | X |
| 2.C.1 Iron and Steel Production | $CO_2$ | X | X | X | X |
| 2.F.6 Other Applications | F-gases | X | X | X | X |
| 3.A Enteric Fermentation | $CH_4$ | X | X | X | X |
| 3.B Manure Management | $CH_4$ | X | X | X | X |
| 3.B Manure Management | $N_2O$ | X | X | X | X |
| 3.D.1 Direct $N_2O$ Emissions From Managed Soils | $N_2O$ | X | X | X | X |
| 3.D.2 Indirect $N_2O$ Emissions From Managed Soils | $N_2O$ | | X | X | X |
| 4.A.1 Forest Land Remaining Forest Land | $CO_2$ | X | X | | X |
| 4.G Harvested Wood Products | $CO_2$ | X | X | | X |
| 4(V) Biomass Burning | $CO_2$ | | X | | X |
| 5.A Solid Waste Disposal | $CH_4$ | X | X | X | X |
| 5.D Wastewater Treatment and Discharge | $CH_4$ | | X | X | X |
| 5.D Wastewater Treatment and Discharge | $N_2O$ | X | X | X | X |

Note: L: Level assessment; T: Trend assessment

Based on the results of the key category analysis, it is tried to increase the Tiers in emissions/removals estimation. However due to resource restrictions, Tier1 approaches have to be used for some key categories, such as $CH_4$ emissions from other sectors, solid fuels and oil and gas systems in energy sectors, $CH_4$ emissions from manure management, $N_2O$ emissions from agricultural soils and wastewater treatment and discharge. Efforts to increase the tiers for all key categories is continuing.

### 1.6. General Uncertainty Evaluation

For calculation of uncertainty, error propagation method (Approach 1) for combining uncertainties, as outlined in Volume 1 (Chapter 3) of the 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) is used. Also for some key categories and non-key categories Monte Carlo Simulation (Approach 2) is implemented. Please refer to Annex 2 for more detailed explanations and distributions of applied techniques. However, general combined uncertainty is estimated with Approach 1 due to the lack of calculated categories.

The general procedures for uncertainty analysis based on the expert judgment are as follows;

- Uncertainties of each activity are allocated by using EFs and AD uncertainties,
- Emissions are estimated for each ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs and $SF_6$) gases,
- The uncertainties for industrial processes data are estimated by TurkStat,
- The uncertainties of F-gases data are estimated by MoEU,
- The uncertainties of agricultural activities data are estimated by TurkStat,
- The uncertainties of waste data are estimated by TurkStat,
- The uncertainties for sectoral energy usage data are estimated by MENR,
- The uncertainties of transport data are estimated by MoTI,
- The uncertainties of forestry and other land use data are estimated by MoAF.

Quantitative estimates of the uncertainties in the emissions are calculated using direct sectoral expert judgement based on the data collection matters considering completeness, accuracy and other parameters. The overall combined uncertainty with LULUCF is 16.4%, and 5.3% without LULUCF by means of Approach 1.

## 1.7. General Assessment of Completeness

*Completeness by source and sink categories:* The inventory is considered to be largely complete with only a few minor sources not estimated, due to either a lack of available information. These sources are considered to be insignificant, when compared with the inventory as a whole. The categories given in Annex 5 were not estimated due to insufficient data or methodology.

*Completeness by geographical coverage:* Geographical coverage of the inventory is complete. It includes all territories of Turkey.

A complete set of CRF tables are provided for all years and estimates are calculated in a consistent manner.

Complete list of source/sink categories reported as "NE" and "IE" is given in Annex 5.

# 2. TRENDS IN GREENHOUSE GAS EMISSIONS

## 2.1. Emission Trends for Aggregated Greenhouse Gas Emissions

Total GHG emissions, excluding the LULUCF sector, were 520.9 Mt $CO_2$ eq. in 2018. This represents an increase of 301.6 Mt $CO_2$ eq. (137.5%) on total emissions in 1990 and a decrease of 2.8 Mt $CO_2$ eq. (0.5%) in 2017.

Net GHG emissions, including the LULUCF sector, were 426.4 Mt $CO_2$ eq. in 2018. This represents an increase of 262.8 Mt $CO_2$ eq. (160.6%) on net emissions in 1990 and an increase of 2.5 Mt $CO_2$ eq. (0.6%) in 2017.

Figure 2.1 presents total and net GHG emissions from 1990 to 2018.

**Figure 2.1 Emission trend for aggregated GHG emissions, 1990-2018**

There is positive trend in the total emissions over the period 1990-2018. However, economic recession had directly caused reduction in the total GHG emissions in 1994, 1999, 2001 and 2008. In these years, total emissions are decreased 2.5%, 0.9%, 6.2% and 1.0% as compared to the previous year's emissions respectively. Although there is no economic recession, total emissions are slightly decreased by 1.8% in 2013 and 0.5% in 2018. This is mainly result of a change in the share of solid fuels for electricity generation as shown in Figure 2.10.

The fluctuations in the emission trends are mainly due to the trends in the economic activities. Therefore, GDP can be thought as the main driver of the GHG emissions in Turkey. It has nearly the same pattern as total GHG emissions for the period 1990-2018. While it was about 365 billion USD in 1990, it reached 1240 billion USD with 2010 constant prices in 2018. Although economic crisis in 1994, 1999, 2001, 2009 caused 4.7%, 3.4%, 6.0%, 4.7% decrease in GDP, Turkish economy grew about 240% for the period 1990-2018.

Population data is another driver of the emission trends in national inventories. The mid-year population of Turkey increased about 47.7% for the period 1990-2018. While it was 55.1 million in 1990, it reached 81.4 million in 2018. Accordingly, $CO_2$ eq. emissions per capita is 6.4 in 2018, while it was 4.0 in 1990.

Figure 2.2 shows trends on various statistics related to Turkish greenhouse gas emissions normalized to 1990 as a baseline year. These values represent the relative change (in comparison with previous year for every year) in each statistics since 1990. The direction of emissions per $GDP trend started to change after 2010, when real GDP began to peak, while population and emissions per capita continued to increase slightly.

**Figure 2.2 GHG emissions per capita and per dollar of GDP, 1990-2018**

Source: https://databank.worldbank.org/home.aspx

Table 2.1 gives summary data for GHG emissions for some selected years between 1990 and 2018.

**Table 2.1 Aggregated GHG emissions by sectors**

**(Mt $CO_2$ eq.)**

| Sector | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Total (exc. LULUCF)** | **219.37** | **247.76** | **298.76** | **337.14** | **398.88** | **472.60** | **497.74** | **523.75** | **520.94** |
| Energy | 139.60 | 166.32 | 216.05 | 243.96 | 287.05 | 340.91 | 359.67 | 379.90 | 373.10 |
| IPPU | 22.84 | 25.25 | 26.23 | 33.63 | 48.15 | 57.08 | 61.12 | 63.61 | 65.20 |
| Agriculture | 45.85 | 43.85 | 42.14 | 42.23 | 44.15 | 55.76 | 58.51 | 62.85 | 64.87 |
| Waste | 11.08 | 12.35 | 14.34 | 17.31 | 19.54 | 18.84 | 18.44 | 17.40 | 17.76 |
| LULUCF | -55.78 | -57.38 | -61.55 | -74.66 | -73.42 | -97.27 | -95.94 | -99.88 | -94.57 |
| Comp. to 1990 (%) | - | 12.94 | 36.19 | 53.69 | 81.83 | 115.43 | 126.90 | 138.76 | 137.47 |

In overall 2018 emissions excluding LULUCF, the energy sector had the largest portion with 71.6%. The energy sector was followed by the IPPU with 12.5%. the agricultural activities with 12.5% and the waste with 3.4%. In Figure 2.3 fluctuations of whole sectors can easily be seen for the entire time period starting with 1990.

**Figure 2.3 GHG Emissions and sinks by sector, 1990-2018**

## 2.2. Emission Trends by Gas

Total $CO_2$ emissions (excluding LULUCF) increased by 176.7% from 1990 to 2018. $CH_4$ emissions (excluding LULUCF) increased by 35.8% and $N_2O$ emissions (excluding LULUCF) increased by 56.8%.

Total $CO_2$ emissions (including LULUCF) increased by 239.4% from 1990 to 2018. There are no significant changes in other GHGs by taking into account the LULUCF sector. $CH_4$ emissions (including LULUCF) increased by 35.6% and $N_2O$ emissions (including LULUCF) increased by 56.9%.

As shown in Figure 2.4, the $CO_2$ emissions show a general increasing trend, while $N_2O$ and $CH_4$ emissions are not changing considerably.

**Figure 2.4 Emission trend of main GHGs, 1990-2018**

Table 2.2 gives summary data for GHG emissions by gas for some selected years between 1990 and 2018.

**Table 2.2 Aggregated GHG emissions excluding LULUCF**

**(Mt $CO_2$ eq.)**

| Gas | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Total** | **219.37** | **247.76** | **298.76** | **337.14** | **398.88** | **472.60** | **497.74** | **523.75** | **520.94** |
| $CO_2$ | 151.51 | 180.90 | 229.79 | 264.20 | 314.38 | 381.33 | 401.24 | 425.33 | 419.19 |
| $CH_4$ | 42.41 | 42.50 | 43.56 | 45.16 | 51.32 | 51.36 | 53.86 | 54.23 | 57.58 |
| $N_2O$ | 24.83 | 23.74 | 24.68 | 26.06 | 29.60 | 35.03 | 37.40 | 38.84 | 38.92 |
| HFCs | NO | NO | 0.12 | 1.15 | 3.05 | 4.64 | 5.02 | 5.16 | 5.08 |
| PFCs | 0.63 | 0.61 | 0.60 | 0.56 | 0.46 | 0.16 | 0.14 | 0.07 | 0.04 |
| $SF_6$ | NO | NO | 0.01 | 0.02 | 0.07 | 0.08 | 0.08 | 0.12 | 0.13 |

Figure 2.5 shows trends in index for each year comparing to previous year by gas for 1990-2018 period. 1990 is assumed as "100" for indexing. All gases are showing increasing trend comparing to 1990 and also to previous years in general. The sharpest trend belongs to F-gases since they increased by 739% in proportion to 1990.

**Figure 2.5 Emission trends in index vs. 1990 by gas, 1990-2018**

### Carbon Dioxide ($CO_2$)

In 2018, $CO_2$ emissions are 419.2 Mt (excluding LULUCF), 6% below the 2017 level and 176.7% above the 1990 level. Figure 2.6 illustrates the trend in $CO_2$ emissions. It is seen that $CO_2$ emissions are dominated by the energy sector which is the main driver for the rising trend in emissions. This situation is caused by growing industrial sector and population in Turkey. In 2018 excluding the LULUCF, energy sector is responsible for 85.8% of the total $CO_2$ emissions while IPPU is responsible for 13.9%. Agriculture and waste sectors do not cause significant amount of $CO_2$ emission.

**Figure 2.6 $CO_2$ emissions by sector, 1990-2018**

### Methane ($CH_4$)

The trend in emissions of $CH_4$ is broken down by source in Figure 2.7, $CH_4$ is the second most significant GHG after $CO_2$ in Turkey since 1990. Emissions of $CH_4$ have increased 35.8% since the base year 1990 and have increased by 6.2% compared to 2017. In 2018, $CH_4$ emissions were 2 303.1 kt excluding the LULUCF.

The major sectors of $CH_4$ are enteric fermentation from agriculture, solid waste disposal from waste source and fugitive emissions in energy sector. Emissions from industrial processes and LULUCF are not significant sources of $CH_4$ in comparison with other sector. Generally, all sectors have risen since 1990.

**Figure 2.7 $CH_4$ emissions by sector, 1990-2018**

### Nitrous Oxide ($N_2O$)

In 2018, $N_2O$ emissions are 130.6 kt without LULUCF and it slightly increased from the level of 2017 (0.3 kt) but 56.8% above the 1990 level. As it is seen from the Figure 2.8, agriculture sector is the main contributor of $N_2O$ emissions in all the years and the share is 70.1% in 2018. Energy sector is responsible for 9.5% and waste sector is responsible for 15.7% of all $N_2O$ emissions. IPPU has a minor share for the $N_2O$ emissions by 4.7%.

**Figure 2.8 $N_2O$ emissions by sector, 1990-2018**

### Fluorinated Gases (HFCs, PFCs, $SF_6$)

The F gases are only caused by the IPPU sector. In 2018, 5 247 kt $CO_2$ eq. of F gases released to the atmosphere. It is seen from Table 2.3 that total F gases emissions increased by 739% since 1990. The main contributor of total F gas emissions is HFCs emissions and it is mainly due to increasing demand of Turkey's refrigerant and air conditioning sector. For PFCs; since EF values decreased by half in years between 2016-2018, as a result emission values of PFCs, $CF_4$ and $C_2F_6$ are decreased by half in same period. In the same years, total production value has also decreased.

**Table 2.3 Fluorinated gases emissions by sector, 1990-2018**

(kt $CO_2$ eq.)

| Year | HFCs | PFCs | $SF_6$ |
|---|---|---|---|
| 1990 | NO | 625.30 | NO |
| 1991 | NO | 863.34 | NO |
| 1992 | NO | 722.59 | NO |
| 1993 | NO | 403.08 | NO |
| 1994 | NO | 710.00 | NO |
| 1995 | NO | 611.44 | NO |
| 1996 | NO | 577.15 | 10.05 |
| 1997 | NO | 574.01 | 11.10 |
| 1998 | NO | 615.00 | 11.90 |
| 1999 | NO | 604.82 | 12.36 |
| 2000 | 115.66 | 601.00 | 13.34 |
| 2001 | 232.00 | 592.20 | 13.16 |
| 2002 | 417.19 | 586.39 | 13.95 |
| 2003 | 628.80 | 581.79 | 15.16 |
| 2004 | 909.37 | 580.13 | 16.44 |
| 2005 | 1 146.88 | 559.96 | 17.67 |
| 2006 | 1 424.19 | 460.96 | 19.40 |
| 2007 | 1 713.19 | 574.44 | 21.04 |
| 2008 | 1 896.14 | 527.72 | 21.98 |
| 2009 | 2 111.28 | 259.26 | 21.30 |
| 2010 | 3 054.28 | 461.74 | 65.48 |
| 2011 | 3 432.64 | 480.36 | 67.37 |
| 2012 | 4 256.83 | 359.06 | 68.58 |
| 2013 | 4 470.24 | 270.60 | 69.02 |
| 2014 | 4 778.45 | 255.42 | 74.88 |
| 2015 | 4 636.96 | 158.99 | 81.83 |
| 2016 | 5 021.15 | 140.67 | 78.61 |
| 2017 | 5 159.25 | 73.11 | 118.33 |
| 2018 | 5 081.90 | 36.62 | 128.39 |

## 2.3. Emission Trends by Sector

**Figure 2.9 GHG emission trend by sectors, 1990-2018**

**1990-2018:** All sectors have an increasing trend from 1990 to 2018 included IPPU (185.5%), energy (167.3%), LULUCF (69.5%), waste (60.3%) and agriculture (41.5%).

The main reasons of the increase for all sectors are population growth, a growing economy and an increase in energy demand.

The main reasons of the rise in removals for LULUCF are improvements in sustainable forest management, afforestation, rehabilitation of degraded forests, reforestations on forest land and conversion of coppices to productive forests in forest land remaining forest land, efficient forest fire management and protection activities, conversions to perennial croplands from annual croplands and grasslands, and conversions to grasslands from annual croplands. The main reasons for the decrease in removals are related to drought and biomass burning as wildfire (e.g. year 2008; 29 749 ha forest area burned), deforestation, conversions to wetlands (flooded land) and settlements.

**2017-2018:** There are both increasing and decreasing trends in the annual change for each sector from 2017 to 2018. The sectors having decreasing trends are LULUCF (5.3%), energy (1.8%). Sectors having increasing trend are IPPU (2.5%) and agriculture (3.2%) waste (2.1%).

The increase in energy sector is mainly originating from combustion emissions in public electricity, heat production sector and transport in 2018. Figure 2.10 shows electricity production from different energy sources for the period, 2016-2018.

**Figure 2.10 Electricity generation and shares by energy resources, 2016-2018**

The decrease in emissions from waste sector is mainly due to the increase in methane recovery processes particularly in recent years. The detailed reasons behind the emission trends and main drivers for all sectors are discussed by each sub-sector in the related chapters.

While Table 2.4 provides contribution of sectors to the net GHG emissions by sectors for some selected years between 1990 and 2018, Table 2.5 shows the same shares for the GHG emissions without LULUCF.

**Table 2.4 Contribution of sectors to the net GHG emissions**

(%)

| Sectors | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Energy** | 85.34 | 87.36 | 91.08 | 92.95 | 88.20 | 90.83 | 89.51 | 89.63 | 88.02 |
| **IPPU** | 13.96 | 13.26 | 11.06 | 12.81 | 14.79 | 15.21 | 15.21 | 15.01 | 15.38 |
| **Agriculture** | 28.03 | 23.03 | 17.76 | 16.09 | 13.56 | 14.86 | 14.56 | 14.83 | 15.30 |
| **Waste** | 6.77 | 6.49 | 6.05 | 6.59 | 6.00 | 5.02 | 4.59 | 4.10 | 4.19 |
| **LULUCF** | -34.10 | -30.14 | -25.95 | -28.44 | -22.56 | -25.91 | -23.88 | -23.56 | -22.31 |

**Table 2.5 Contribution of sectors to the GHG emissions without LULUCF**

(%)

| Sectors | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Energy** | 63.64 | 67.13 | 72.32 | 72.36 | 71.96 | 72.14 | 72.26 | 72.53 | 71.24 |
| **IPPU** | 10.41 | 10.19 | 8.78 | 9.98 | 12.07 | 12.08 | 12.28 | 12.15 | 12.45 |
| **Agriculture** | 20.90 | 17.70 | 14.10 | 12.53 | 11.07 | 11.80 | 11.76 | 12.00 | 12.39 |
| **Waste** | 5.05 | 4.98 | 4.80 | 5.13 | 4.90 | 3.99 | 3.70 | 3.32 | 3.39 |

## Energy

As in most countries, the energy system in Turkey is largely driven by the fuel combustion, followed by fugitive emissions from fuels and then $CO_2$ transport and storage. In 2018, emissions from the energy sector are 71.2% of total emissions, excluding LULUCF. Emissions in $CO_2$ eq. from the energy sector are reported in Table 2.6 and showed in Figure 2.11.

$CO_2$ emissions, 96.4% of the total energy sector emissions, showed an increase by 177.0% from 1990 to 2018. $CH_4$ emissions are just 2.6% of the total, increased by 23.2% in comparison with the 1990. $N_2O$ emissions, with 1.0% contribution to total emissions of energy sector, show 90.4% increase in proportion to year 1990.

**Table 2.6 Total emissions from the energy sector by source**

**(kt $CO_2$ eq.)**

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Total** | 139 601 | 166 318 | 216 054 | 243 965 | 287 047 | 340 907 | 359 671 | 379 901 | 373 101 |
| 1.A Fuel combustion | 135 091 | 162 296 | 209 908 | 238 213 | 278 821 | 335 411 | 351 075 | 373 202 | 365 439 |
| 1.A.1 Energy industries | 37 253 | 50 465 | 77 743 | 90 458 | 113 324 | 134 702 | 143 963 | 154 971 | 158 490 |
| 1.A.2 Manufacturing industries and construction | 37 162 | 39 995 | 57 936 | 63 004 | 52 332 | 59 585 | 60 071 | 60 180 | 59 578 |
| 1.A.3 Transport | 26 969 | 34 113 | 36 465 | 42 041 | 45 392 | 75 798 | 81 841 | 84 659 | 84 502 |
| 1.A.4 Other sectors | 33 707 | 37 722 | 37 764 | 42 709 | 67 773 | 65 327 | 65 201 | 73 391 | 62 869 |
| 1.B Fugitive emissions from fuels | 4 510 | 4 023 | 6 145 | 5 752 | 8 226 | 5 496 | 8 596 | 6 699 | 7 662 |
| 1.B.1 Solid fuels | 3 598 | 2 985 | 4 836 | 3 941 | 6 151 | 2 733 | 5 896 | 3 681 | 4 885 |
| 1.B.2 Oil and natural gas | 912 | 1 038 | 1 309 | 1 811 | 2 075 | 2 763 | 2 700 | 3 017 | 2 777 |
| 1.C $CO_2$ transport and storage | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 |

**Figure 2.11 Trend of total emissions from energy sector, 1990-2018**

GHG emissions of energy sector, in $CO_2$ eq., show an increase by 160.6% from 1990 to 2018. Generally, an upward trend is noted from 1990-2018.

## IPPU

Emissions from industrial process and product use sector have a share of 12.4% of Turkey's total emissions excluding LULUCF in 2018. $CO_2$ emissions in year 2018, are 89.1% of total IPPU emissions. $N_2O$ has 2.8% share in IPPU emissions and increased by 71.4% compared to 1990. Whereas, $CH_4$ has a minor impact. Emissions by each subsector of IPPU are tabulated in Table 2.7 for the 1990-2018 period. Figure 2.12 shows the trend for the IPPU related emissions by cumulating its subsectors.

**Table 2.7 Total emissions from the industrial process and product use sector by source**

**(kt $CO_2$ eq.)**

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Total** | 22 836 | 25 247 | 26 227 | 33 631 | 48 149 | 57 082 | 61 121 | 63 610 | 65 204 |
| 2.A Mineral industry | 13 424 | 17 549 | 18 418 | 23 246 | 33 394 | 38 479 | 42 004 | 44 274 | 43 819 |
| 2.B Chemical industry | 1 629 | 1 476 | 1 061 | 1 321 | 1 903 | 2 788 | 2 159 | 2 004 | 3 093 |
| 2.C Metal industry | 7 601 | 6 019 | 6 342 | 7 453 | 9 301 | 10 829 | 11 712 | 11 903 | 12 876 |
| 2.D Non-energy products from fuels and solvent use | 183 | 203 | 277 | 446 | 432 | 266 | 146 | 152 | 206 |
| 2.E Electronic industry | NO | NO | NO | NO | 42 | 42 | 42 | 45 | 57 |
| 2.F Product uses as ODS substitutes | NO | NO | 116 | 1 147 | 3 054 | 4 637 | 5 021 | 5 159 | 5 082 |
| 2.G Other product manufacture and use | NO | NO | 13 | 18 | 23 | 40 | 36 | 73 | 71 |

**Figure 2.12 Trend of total emissions from IPPU sector, 1990-2018**

IPPU related emissions increased by 185.5% from 1990 to 2018. Due to the growth of population and the production especially for the recent decade, emissions from IPPU sector are increased.

## Agriculture

Enteric fermentation is by far the largest source of GHG emissions of agriculture in Turkey since 1990. The agriculture sector includes emissions from the enteric fermentation, manure management, rice cultivation, agricultural soils, field burning of agricultural residues and urea application. In 2018, the agriculture sector accounted for 12.4% of total emissions in Turkey. Enteric fermentation and agricultural soils dominate the trends in this sector between 1990 and 2018 as seen in Table 2.8 and they have an increase by 49.4% and 35.0% compared to 1990 respectively.

Most important portion in each gas is $CH_4$ with 56.0%, then comes $N_2O$ with 42.1% share in agriculture sector emissions. $CO_2$ has the lowest contribution with 1.9%.

**Table 2.8 Total emissions from agriculture sector by source**

**(kt $CO_2$ eq.)**

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Total** | 45 849 | 43 848 | 42 138 | 42 234 | 44 149 | 55 761 | 58 514 | 62 846 | 64 872 |
| 3.A Enteric fermentation | 22 314 | 21 705 | 19 124 | 19 663 | 20 912 | 26 888 | 26 923 | 30 039 | 32 060 |
| 3.B Manure management | 5 432 | 5 523 | 5 151 | 4 754 | 5 357 | 6 905 | 7 007 | 7 642 | 8 443 |
| 3.C Rice cultivation | 100 | 113 | 128 | 183 | 202 | 240 | 243 | 234 | 252 |
| 3.D Agricultural soils | 17 196 | 15 750 | 16 777 | 16 718 | 16 814 | 20 744 | 22 880 | 23 316 | 22 697 |
| 3.F Field burning of agricultural residues | 347 | 332 | 340 | 302 | 219 | 174 | 164 | 165 | 163 |
| 3.H Urea application | 460 | 426 | 617 | 613 | 645 | 811 | 1 295 | 1 450 | 1 257 |

**Figure 2.13 Trend of total emissions from agriculture sector, 1990-2018**

## LULUCF

GHG emissions of LULUCF sector from sources and removals by sinks are estimated and reported for categories of managed lands: forest land, cropland, grassland, wetlands, settlements, harvested wood products, other land and others.

In 2018, total $CO_2$ eq. emissions and removals of the LULUCF sector has decreased 5.3% compared to 2017. Table 2.9 reports emissions and removals from the LULUCF sector by source.

**Table 2.9 Total emissions and removals from the LULUCF sector by source**

**(kt $CO_2$ eq.)**

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Total** | -55 777 | -57 383 | -61 553 | -74 658 | -73 419 | -97 265 | -95 939 | -99 882 | -94 570 |
| 4.A Forest land | -52 830 | -54 963 | -57 890 | -69 356 | -67 614 | -87 669 | -85 233 | -90 195 | -84 849 |
| 4.B Cropland | 0.69 | 153 | 38 | 207 | 453 | 457 | 344 | 368 | 357 |
| 4.C Grassland | 0.03 | 291 | 97 | 259 | 636 | 983 | 656 | 705 | 708 |
| 4.D Wetlands | 0.01 | 157 | 176 | 28 | 413 | -20 | 271 | 288 | 222 |
| 4.E Settlements | NO, IE | 132 | 145 | 273 | 426 | 419 | 406 | 413 | 407 |
| 4.F Other land | NO, IE | 181 | 187 | 310 | 601 | 764 | 617 | 653 | 650 |
| 4.G Harvested wood products | -2 948 | -3 333 | -4 305 | -6 379 | -8 334 | -12 200 | -13 000 | -12 115 | -12 135 |

**Figure 2.14 Trend of total emissions from the LULUCF sector, 1990-2018**

LULUCF emissions or removals, in $CO_2$ equivalent, are variable over the reporting period 1990-2018 as seen in Figure 2.14. Generally, decreases in removals were influenced by fires and drought in the relevant areas. Moreover, rises are originated mainly from forest management, afforestation, rehabilitation of degraded forests, reforestations on forest land and etc.

### Waste

The waste sector includes GHG emissions from the treatment and disposal of wastes, open burning, wastewater treatment and discharge. Waste incineration emissions are included in inventory however it is reported under energy sector. Waste sector GHG emissions are tabulated in Table 2.10. Total waste emissions for the year 2018 are 3.4% of total GHG emissions (without LULUCF). Considering emissions by gas, the most important GHG is $CH_4$ which accounts for 65.7% of the total and shows an increase of 21.5% from 1990 to 2018. $N_2O$ levels have increased by 318.1% whereas $CO_2$ decreased by 95.3%; these gases account for 34.3% and 0.007%, respectively.

**Table 2.10 Total emissions from the waste sector by source**

**(kt $CO_2$ eq.)**

| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **Total** | 11 081 | 12 348 | 14 341 | 17 310 | 19 537 | 18 845 | 18 435 | 17 396 | 17 764 |
| 5.A Solid waste disposal | 6 730 | 7 628 | 9 582 | 11 562 | 12 272 | 11 231 | 10 477 | 9 043 | 8 864 |
| 5.B Biological treatment of solid waste | 16 | 13 | 17 | 28 | 30 | 23 | 24 | 23 | 20 |
| 5.C Incineration and open burning of waste | 105 | 103 | 87 | 47 | 37 | 2 | 4 | 3 | 2 |
| 5.D Wastewater treatment and discharge | 4 230 | 4 604 | 4 656 | 5 673 | 7 198 | 7 588 | 7 931 | 8 327 | 8 877 |

**Figure 2.15 Trend of total emissions from the waste sector, 1990-2018**

Figure 2.15 shows trends in waste sector between 1990-2018. The trend is mainly driven by wastewater treatment and discharge with 50.0% of the emissions were from, followed by solid waste disposal 49.9% from, 0.12% from biological treatment of solid waste and 0.01% from open burning of waste. Total emissions, in $CO_2$ equivalent, increased by 2.1% from 2017 to 2018.

## 2.4. Emission Trends for Indirect Greenhouse Gases

Emission trends of $NO_X$, CO, NMVOC and $SO_2$ from 1990 to 2018 are given in Table 2.11.

**Table 2.11 Total emissions for indirect greenhouse gases, 1990-2018**

(kt)

| Gas | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| $NO_X$ | 255 | 1 041 | 1 492 | 1 301 | 956 | 801 | 805 | 778 | 783 |
| CO | 2 043 | 5 762 | 8 763 | 3 746 | 3 426 | 2 482 | 2 288 | 2 115 | 1 596 |
| NMVOC | 829 | 1 231 | 1 526 | 1 024 | 1 014 | 1 014 | 990 | 1 014 | 989 |
| $SO_2$ | 1 687 | 1 844 | 2 238 | 2 001 | 2 555 | 1 947 | 2 251 | 2 361 | 2 524 |

**1990-2018:** Almost all indirect gases have an increasing trend from 1990 to 2018 included $NO_X$ (207.2%), $SO_2$ (49.6) and NMVOC (19.4%) except CO with a decreasing trend 21.9%.

**2017-2018:** There are both increasing and decreasing trends in the annual change for each gas from 2017 to 2018. The gases having increasing trends are $SO_2$ (6.9%) and $NO_X$ (0.7%). The gases have decreasing trends are CO (24.6%) and NMVOC (2.4%).

# 3. ENERGY (CRF Sector 1)

## 3.1. Sector Overview

The energy sector includes emissions from the combustion of fossil fuels (1.A.1 energy industries; 1.A.2 manufacturing industries and construction; 1.A.3 transport; and 1.A.4 other sectors; as well as fugitive emissions from fossil fuels (1.B) and $CO_2$ transportation and storage (1.C).

Energy sector is the major source of Turkish anthropogenic GHG emissions. In overall 2018 GHG emissions (excluding LULUCF), the energy sector had the largest portion with 71.6%.

Energy sector $CO_2$ emissions constituted 85.8% of total $CO_2$ emissions in 2018. The non-$CO_2$ emissions from energy-related activities represented rather small portion of the total national emissions. $CH_4$ emissions are 16.6% of total national $CH_4$ emissions and $N_2O$ emissions are 9.5% of total $N_2O$ emissions in 2018.

Total emissions from the energy sector for 2018 were estimated to be 373 Mt $CO_2$ eq. (Table 3.1) Energy industries were the main contributor, accounting for 42.5% of emissions from the energy sector. It is followed by transport sector with 22.6%, other sector with 16.9% and manufacturing industries with 16% (Table 3.2).

Energy sector GHG emissions increased by 167% between 1990 and 2018 whereas annual emissions from 2017 to 2018 decreased by 1.8% (6 799 Mt $CO_2$ eq.).

**Table 3.1 Energy sector emissions by gas, 1990-2018**

(kt)

| Year | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ eq. |
|---|---|---|---|---|
| 1990 | 129 882 | 310.8 | 6.5 | 139 601 |
| 1991 | 134 500 | 301.6 | 6.5 | 143 985 |
| 1992 | 140 776 | 303.1 | 6.7 | 150 337 |
| 1993 | 147 170 | 296.0 | 7.6 | 156 827 |
| 1994 | 144 118 | 280.0 | 7.5 | 153 349 |
| 1995 | 156 827 | 286.2 | 7.8 | 166 318 |
| 1996 | 174 383 | 286.3 | 8.3 | 184 018 |
| 1997 | 186 039 | 305.1 | 8.4 | 196 178 |
| 1998 | 185 609 | 311.2 | 8.3 | 195 864 |
| 1999 | 182 763 | 343.3 | 8.3 | 193 817 |
| 2000 | 204 511 | 360.8 | 8.5 | 216 054 |
| 2001 | 188 624 | 330.2 | 7.9 | 199 233 |
| 2002 | 195 422 | 320.8 | 8.0 | 205 832 |
| 2003 | 209 683 | 314.2 | 9.3 | 220 300 |
| 2004 | 215 288 | 314.2 | 10.1 | 226 139 |
| 2005 | 232 409 | 337.5 | 10.5 | 243 965 |
| 2006 | 247 926 | 347.3 | 11.2 | 259 959 |
| 2007 | 276 375 | 425.0 | 12.7 | 290 771 |
| 2008 | 271 096 | 485.2 | 13.6 | 287 279 |
| 2009 | 276 022 | 492.2 | 14.0 | 292 501 |
| 2010 | 270 820 | 491.2 | 13.2 | 287 047 |
| 2011 | 291 845 | 504.4 | 14.1 | 308 666 |
| 2012 | 304 432 | 525.3 | 9.8 | 320 489 |
| 2013 | 292 914 | 466.6 | 9.9 | 307 523 |
| 2014 | 309 259 | 533.7 | 10.6 | 325 767 |
| 2015 | 329 782 | 296.1 | 12.5 | 340 907 |
| 2016 | 345 298 | 419.8 | 13.0 | 359 671 |
| 2017 | 366 898 | 355.7 | 13.8 | 379 901 |
| 2018 | 359 819 | 382.9 | 12.4 | 373 101 |

**Table 3.2 Energy sector GHG emissions, 1990-2018**

(kt $CO_2$ eq.)

| | | Fuel combustion | | | | | Fugitive emissions from fuels | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Energy | Fuel combustion total | Energy industries | Manufacturing industries and construction | Transport | Other sectors | Total fugitive emissions | Solid fuels | Oil and natural gas | $CO_2$ transport and storage |
| 1990 | 139 601 | 135 091 | 37 253 | 37 162 | 26 969 | 33 707 | 4 510 | 3 598 | 912 | 0.13 |
| 1991 | 143 985 | 139 685 | 38 791 | 40 335 | 25 673 | 34 887 | 4 300 | 3 219 | 1 080 | 0.13 |
| 1992 | 150 337 | 146 092 | 43 324 | 39 324 | 26 366 | 37 079 | 4 245 | 3 177 | 1 067 | 0.13 |
| 1993 | 156 827 | 152 694 | 42 752 | 39 986 | 32 143 | 37 812 | 4 133 | 3 114 | 1 020 | 0.13 |
| 1994 | 153 349 | 149 350 | 49 059 | 35 876 | 30 640 | 33 775 | 3 999 | 2 998 | 1 001 | 0.13 |
| 1995 | 166 318 | 162 296 | 50 465 | 39 995 | 34 113 | 37 722 | 4 023 | 2 985 | 1 038 | 0.13 |
| 1996 | 184 018 | 179 958 | 54 437 | 50 586 | 36 271 | 38 664 | 4 060 | 2 967 | 1 092 | 0.13 |
| 1997 | 196 178 | 191 814 | 59 581 | 56 029 | 34 690 | 41 515 | 4 364 | 3 187 | 1 177 | 0.13 |
| 1998 | 195 864 | 191 119 | 65 164 | 55 470 | 32 782 | 37 704 | 4 745 | 3 565 | 1 180 | 0.13 |
| 1999 | 193 817 | 188 096 | 70 360 | 47 365 | 34 617 | 35 753 | 5 720 | 4 481 | 1 239 | 0.13 |
| 2000 | 216 054 | 209 908 | 77 743 | 57 936 | 36 465 | 37 764 | 6 145 | 4 836 | 1 309 | 0.13 |
| 2001 | 199 233 | 193 530 | 80 022 | 45 656 | 36 455 | 31 397 | 5 702 | 4 387 | 1 315 | 0.13 |
| 2002 | 205 832 | 200 415 | 74 138 | 57 112 | 36 234 | 32 930 | 5 418 | 4 059 | 1 358 | 0.13 |
| 2003 | 220 300 | 215 110 | 74 371 | 66 682 | 37 825 | 36 232 | 5 190 | 3 664 | 1 526 | 0.13 |
| 2004 | 226 139 | 221 005 | 75 539 | 63 857 | 42 048 | 39 561 | 5 134 | 3 568 | 1 566 | 0.13 |
| 2005 | 243 965 | 238 213 | 90 458 | 63 004 | 42 041 | 42 709 | 5 752 | 3 941 | 1 811 | 0.13 |
| 2006 | 259 959 | 253 874 | 96 129 | 70 084 | 45 424 | 42 236 | 6 086 | 4 119 | 1 966 | 0.13 |
| 2007 | 290 771 | 282 821 | 113 570 | 71 874 | 52 099 | 45 279 | 7 949 | 5 725 | 2 224 | 0.13 |
| 2008 | 287 279 | 278 869 | 118 939 | 47 354 | 48 166 | 64 410 | 8 410 | 6 118 | 2 291 | 0.13 |
| 2009 | 292 501 | 284 372 | 119 280 | 46 226 | 47 907 | 70 959 | 8 128 | 6 061 | 2 067 | 0.13 |
| 2010 | 287 047 | 278 821 | 113 324 | 52 332 | 45 392 | 67 773 | 8 226 | 6 151 | 2 075 | 0.13 |
| 2011 | 308 666 | 299 601 | 124 975 | 52 585 | 47 386 | 74 656 | 9 065 | 6 662 | 2 403 | 0.13 |
| 2012 | 320 489 | 311 108 | 125 944 | 61 052 | 62 525 | 61 586 | 9 381 | 6 851 | 2 530 | 0.13 |
| 2013 | 307 523 | 299 000 | 120 773 | 52 978 | 68 865 | 56 384 | 8 524 | 6 324 | 2 199 | 0.13 |
| 2014 | 325 767 | 315 551 | 131 474 | 54 438 | 73 559 | 56 079 | 10 216 | 7 318 | 2 898 | 0.13 |
| 2015 | 340 907 | 335 411 | 134 702 | 59 585 | 75 798 | 65 327 | 5 496 | 2 733 | 2 763 | 0.13 |
| 2016 | 359 671 | 351 075 | 143 963 | 60 071 | 81 841 | 65 201 | 8 596 | 5 896 | 2 700 | 0.13 |
| 2017 | 379 901 | 373 202 | 154 971 | 60 180 | 84 659 | 73 391 | 6 699 | 3 681 | 3 017 | 0.13 |
| 2018 | 373 101 | 365 439 | 158 490 | 59 578 | 84 502 | 62 869 | 7 662 | 4 885 | 2 777 | 0.13 |

Energy sector GHG emissions mainly are coming from stationary combustion. Total emissions from stationary combustion are 281 Mt $CO_2$ eq. in 2018, equal to 54% of total national GHG emissions (excluding LULUCF).

The energy industries subsector (1.A.1) contributed 158.5 Mt $CO_2$ eq. in 2018 while the GHG emissions from manufacturing industries and construction subsector (1.A.2) emissions were 59.6 Mt $CO_2$ eq. and GHG emissions from other sectors (1.A.4) were 62.9 Mt. The transport sector GHG emissions were 84.5 Mt in the same year.

GHG emissions from stationary combustion increased by 160% (172.8 Mt $CO_2$ eq.) between 1990 and 2018, and decreased by 2.6% (7.6 Mt $CO_2$ eq.) between 2017 and 2018.

**Figure 3.1 GHG emissions from fuel combustion, 1990-2018**

In 2018, transport contributed 84.5 Mt $CO_2$ eq., which is 16.2% of total GHG emissions (excluding LULUCF). The major source of transport emissions in Turkey is road transportation. It accounts for 93.4% of transport emissions. It is followed by domestic aviation while other sources are far smaller: domestic aviation with 4.4% and domestic navigation with 1.1%. Pipeline transport contribution was 0.6% and railway contribution was 0.5%.

Fuel used in international aviation and marine bunkers is reported separately from the national total. In 2018, international bunker GHG emissions were 15.0 Mt $CO_2$ eq.

Emissions from transport sector increased 213% (84.5 Mt $CO_2$ eq.) in 2018 compared to 1990. In the same period increase in road transportation emissions was 218.5%, in domestic aviation it was 299.6% and in domestic navigation it was 82.9%. Emissions from railway transport decreased by 39.7% between 1990 and 2018.

Total fugitive emissions for 2018 were 7.7 Mt $CO_2$ eq., representing 1.5% of total GHG emissions (excluding LULUCF). Oil and natural gas systems contributed 36.2%, solid fuels account for the remaining 63.8% of fugitive emissions.

Overall fugitive emissions increased 70% between 1990 and 2018. In 2014 a serious mine accident happened and many underground mines were closed in the following year as a precaution, therefore in 2015 fugitive emissions were decreased remarkably. In 2018, the underground coal production activity increased and therefore in 2018 fugitive emissions from solid fuels were increased. In overall, from 1990 to 2018, fugitive emissions from oil and natural gas systems increased by 205%. Emissions from solid fuels increased by 36% in the same period.

**Figure 3.2 Fugitive emissions, 1990-2018**

2006 IPCC Guidelines are used for energy sector emission estimation. The methodology for emissions from stationary energy sectors is a mix of T1, T2 and T3 approaches. In transport sector, T1 and T2 approaches have been used. Fugitive emissions were estimated by T1 approach. (Table 3.3)

**Table 3.3 Summary of methods and emission factors used in energy sector**

| | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| **GHG sources and sink categories** | **Method applied** | **Emission factor** | **Method applied** | **Emission factor** | **Method applied** | **Emission factor** |
| **1. Energy** | T1,T2,T3 | CS,D,PS | T1,T2,T3 | D,PS | T1,T2,T3 | D,PS |
| A. Fuel combustion | T1,T2,T3 | CS,D,PS | T1,T2,T3 | D,PS | T1,T2,T3 | D,PS |
| 1. Energy industries | T2,T3 | CS,D,PS | T2,T3 | D,PS | T2,T3 | D,PS |
| 2. Manufacturing industries and construction | T1,T2 | CS,D | T1 | D | T1 | D |
| 3. Transport | T1,T2 | CS,D | T1,T2 | D | T1,T2 | D |
| 4. Other sectors | T1,T2 | CS,D | T1 | D | T1 | D |
| B. Fugitive emissions from fuels | T1 | D | T1 | D | T1 | D |
| 1. Solid fuels | NA | NA | T1 | D | NA | NA |
| 2. Oil and natural gas | T1 | D | T1 | D | T1 | D |
| C. $CO_2$ transport and storage | T1 | D | - | - | - | - |

Country specific and plant specific carbon contents of liquid, solid and gaseous fuels are used for $CO_2$ emissions estimation. For $CH_4$ and $N_2O$ emissions, 2006 IPCC default emissions factors are used.

### Sector QA/QC and Verification

Quality control for energy category was performed on the basis of QA/QC plan of Turkey. All emission factors and implied emission factors are compared with 2006 IPCC Guideline defaults and any outlines were examined. In this inventory, 1A2 and 1A4 sectorial approach emissions and 1AB reference approach fuel combustion emissions were calculated on SAS and it was double checked by the calculations on the Excel sheets by two different experts and any findings were corrected.

In 2017 August, energy sector expert, from Finland, have come to TurkStat to review the energy sector in scope of a project coordinated by TurkStat. Moreover, Turkish inventory have been reviewed by ERT in 2017 September. Based on those findings improvements were done in the energy sector. These improvements are explained and the effect of the recalculations are shown with in the relevant sectorial subtitle in NIR submitted in 2018. Another QA process was also conducted in 2020 by an expert from CITEPA for this sector.

The main critic during the reviews is the consistency of the energy sector. This is because the national energy balance tables, which are the main data source of energy sector, are not in time series. Inconstancies come to exist when the national energy balance tables are used in the time series inventory calculations. In order to overcome this problem national energy balance tables should be reallocated and made consistent in the time series. This problem will be handled in the following years.

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

The major source of GHGs in Turkey is the fossil fuel combustion. The emissions from fossil fuel combustion are calculated by TurkStat with cooperation with the Ministry of Energy and National Resources(MENR) and the Ministry of Transport and Infrastructure (MoTI). The emissions from public electricity and heat production were calculated by MENR and the emissions from transport were calculated by MoTI, and the other energy sub-sectors were calculated by TurkStat. 2006 IPCC Guidelines were used in emissions estimation for all energy subcategories.

The emissions from public electricity and heat production (1.A.1.a) are calculated on the basis of plant specific fuel consumption and net calorific values (NCVs) with country specific carbon contents of fuels. Technology specific $CH_4$ and $N_2O$ emission factors from 2006 IPCC Guidelines are used for 1.A.1.a category for since 2003 and 2006 IPCC Guidelines default $CH_4$ and $N_2O$ EFs are used for 1990-2002 period since combustion technology data is available from 2003 onward for this category.

For petroleum refining sector (1.A.1.b), fuel consumption data, NCVs and carbon content of fuels are compiled directly from the refineries. In the same way for manufacture of solid fuels (1.A.1.c) categories, plant specific AD and plant specific carbon content are used in the emission estimation. 2006 IPCC Guidelines default EFs are used for $CH_4$ and $N_2O$ emission estimation.

Emissions from manufacturing industry and construction and other sectors (1.A.2), (1.A.4) were estimated by using energy balance tables. For $CO_2$ emission estimation both country specific and default carbon contents and oxidation factors are used depending on the data availability. 2006 IPCC Guidelines default EFs are used for $CH_4$ and $N_2O$ emission estimation.

Transportation sector (1.A.3) consists of road transportation, domestic aviation, railways, domestic navigation and pipeline transportation. Data availability in road transportation, navigation sector and railways allows mostly T1 methodology in the emission estimations. Country specific carbon content of diesel oil and residual fuel oil are used for $CO_2$ emission estimations but for gasoline and liquefied petroleum gas (LPG) 2006 IPCC default emission factors are used. T2 methodology was used for the calculation of emissions from domestic aviation. Also T2 methodology was used for the calculation of $CO_2$ emissions from pipeline transportation. 2006 IPCC Guidelines default EFs are used for $CH_4$ and $N_2O$ emission estimation. The following table summarizes the data source for the 1A sectors.

**Table 3.4 Summary table for the data source in fuel combustion (1A) sector**

| Category | Data Source |
|---|---|
| 1A1a Electricity and Heat Production | Plant specific |
| 1A1b Petroleum Refining | Plant specific |
| 1A1c Manufacturing of Solid Fuels and Other Energy Industries | Plant specific |
| 1A2 Manufacturing Industries and Construction | National energy balance table |
| 1A3 Transport | See chapter 3.2.6 |
| 1A4 Other Sectors | National energy balance table |
| 1AB Fuel Combustion Reference Approach | National energy balance table |
| 1AD Feedstocks Reductants and Other non-Energy use of fuels | See chapter 3.2.3 |

National energy balance tables, which are published by the MENR every year, are the most important input for the energy sector emission calculations. The source of data for the electricity production sector of national energy balance is Turkish Electricity Transmission Corporation (TEİAŞ). The data that TEİAŞ sends includes electricity generation, fuel consumption in both original units and TJ, with respect to energy resources and license type of electricity generators. After the data is compared with previous years, it is directly used in the relevant sections of the energy balance table. For the supply part of national energy balance table (indigenous production, import, export, bunkers, stock change), the administrative sources of relevant stakeholders such as EPDK, BOTAŞ, TEİAŞ, TTK, TKİ, MTA, MAPEG are utilized. For the demand part of national energy balance table, the industry sector data is collected through questionnaires applied by MENR/EİGM to the relevant companies/firms. For the other sectors, administrative sources of relevant stakeholders are used. In the process of compiling data, the sectoral reports of stakeholders are examined, as well as time series analysis and quality control with respect to both energy resources and sectors are applied. The following table shows the country specific carbon content (as ton carbon / TJ fuel) of fuels used in calculating the $CO_2$ emissions. NCVs can be found Annex 3.

**Table 3.5 Country specific carbon contents of fuels**

| Fuel types | Unit | 1990 | 2000 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Hard coal | t /TJ | 25.79 | 26.38 | 27.28 | 26.16 | 24.16 | 26.43 | 26.08 |
| Lignite | t/TJ | 32.79 | 31.61 | 31.57 | 30.57 | 30.51 | 30.05 | 30.51 |
| Coke | t/TJ | 30.14 | 30.14 | 29.95 | 30.10 | 29.55 | 30.61 | 29.48 |
| Petrocoke | t/TJ | 26.55 | 26.55 | 26.55 | 26.55 | 26.55 | 26.55 | 26.55 |
| Fuel oil | t/TJ | 21.33 | 21.33 | 21.33 | 21.33 | 21.33 | 21.33 | 21.33 |
| Diesel | t/TJ | 20.03 | 20.03 | 20.03 | 20.03 | 20.03 | 20.03 | 20.03 |
| Naphta | t/TJ | 20.13 | 20.13 | 20.13 | 20.13 | 20.13 | 20.13 | 20.13 |
| Natural gas | t/TJ | 15.13 | 15.13 | 15.17 | 15.19 | 15.19 | 15.18 | 15.08 |

The following table shows the country specific oxidation factors of fuels used in calculating the $CO_2$ emissions factors.

**Table 3.6 Country specific oxidation factor of fuels**

| Fuel types | 1990 | 2000 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| Hard coal | 0.988 | 0.988 | 0.985 | 0.963 | 0.963 | 0.975 | 0.975 |
| Lignite | 0.950 | 0.950 | 0.953 | 0.960 | 0.960 | 0.973 | 0.973 |
| Fuel oil | 0.984 | 0.984 | 0.984 | 0.984 | 0.984 | 0.984 | 0.984 |
| Diesel | 0.984 | 0.984 | 0.984 | 0.984 | 0.984 | 0.984 | 0.984 |

The following table shows the $CO_2$ emissions factors of all the fuels.

Either country specific carbon contents or IPCC default carbon contents are used in the calculations depending on the data availability. $CO_2$ EFs are calculated by the formula below.

$CO_2$ EF = C content of fuel x Oxidation factor of fuel x (44/12)

Country specific carbon content and oxidation rates were calculated through fuel analysis and ash-slag or stack gas analysis reports.

**Table 3.7 $CO_2$ emission factors of fuels**

| Fuel types | Unit | 1990 | 2000 | 2010 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| Hard coal | t/TJ | 93.4 | 95.5 | 98.6 | 92.4 | 85.3 | 94.5 | 94.1 |
| Lignite | t/TJ | 114.2 | 110.1 | 110.3 | 107.6 | 107.4 | 107.2 | 107.5 |
| Asphaltite | t/TJ | 96.1 | 96.1 | 96.1 | 96.1 | 96.1 | 96.1 | 96.1 |
| Coke | t/TJ | 110.5 | 110.5 | 109.8 | 110.4 | 108.3 | 112.2 | 108.1 |
| Coal tar | t/TJ | 80.7 | 80.7 | 80.7 | 80.7 | 80.7 | 80.7 | 80.7 |
| Crude oil | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| Petrocoke | t/TJ | 97.4 | 97.4 | 97.4 | 97.4 | 97.4 | 97.4 | 97.4 |
| Fuel oil | t/TJ | 77.0 | 77.0 | 77.0 | 77.0 | 77.0 | 77.0 | 77.0 |
| Diesel | t/TJ | 72.3 | 72.3 | 72.3 | 72.3 | 72.3 | 72.3 | 72.3 |
| Gasoline | t/TJ | 69.3 | 69.3 | 69.3 | 69.3 | 69.3 | 69.3 | 69.3 |
| LPG | t/TJ | 63.1 | 63.1 | 63.1 | 63.1 | 63.1 | 63.1 | 63.1 |
| Rafinery gas | t/TJ | 57.6 | 57.6 | 57.6 | 57.6 | 57.6 | 57.6 | 57.6 |
| Aviation fuel | t/TJ | 71.5 | 71.5 | 71.5 | 71.5 | 71.5 | 71.5 | 71.5 |
| Kerosene | t/TJ | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 | 71.9 |
| Naphta | t/TJ | 72.7 | 72.7 | 72.7 | 72.7 | 72.7 | 72.7 | 72.7 |
| Intermediate products | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| Base oils | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| White spirit | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| Bitumen | t/TJ | 80.7 | 80.7 | 80.7 | 80.7 | 80.7 | 80.7 | 80.7 |
| Other petroleum products | t/TJ | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 | 73.3 |
| Natural gas | t/TJ | 55.5 | 55.5 | 55.6 | 55.7 | 55.7 | 55.6 | 55.6 |
| Fuel wood | t/TJ | 111.8 | 111.8 | 111.8 | 111.8 | 111.8 | 111.8 | 111.8 |
| Animal&Vegetable waste | t/TJ | 100.1 | 100.1 | 100.1 | 100.1 | 100.1 | 100.1 | 100.1 |
| Biofuels | t/TJ | 70.8 | 70.8 | 70.8 | 70.8 | 70.8 | 70.8 | 70.8 |

$CO_2$, $CH_4$ and $N_2O$ Emissions from fuel combustion were calculated for the period 1990-2018

**Table 3.8 Emissions from fuel combustion (1A), 1990-2018**

| | | | | (kt) |
|---|---|---|---|---|
| **Year** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2$ eq.** |
| 1990 | 129 662 | 139.3 | 6.5 | 135 091 |
| 1991 | 134 236 | 140.2 | 6.5 | 139 685 |
| 1992 | 140 522 | 143.5 | 6.7 | 146 092 |
| 1993 | 146 939 | 140.0 | 7.6 | 152 694 |
| 1994 | 143 899 | 128.9 | 7.5 | 149 350 |
| 1995 | 156 618 | 133.7 | 7.8 | 162 296 |
| 1996 | 174 175 | 132.3 | 8.3 | 179 958 |
| 1997 | 185 832 | 138.8 | 8.4 | 191 814 |
| 1998 | 185 415 | 129.2 | 8.3 | 191 119 |
| 1999 | 182 585 | 121.6 | 8.3 | 188 096 |
| 2000 | 204 343 | 121.7 | 8.5 | 209 908 |
| 2001 | 188 469 | 108.3 | 7.9 | 193 530 |
| 2002 | 195 274 | 110.0 | 8.0 | 200 415 |
| 2003 | 209 538 | 112.5 | 9.3 | 215 110 |
| 2004 | 215 148 | 114.5 | 10.1 | 221 005 |
| 2005 | 232 267 | 113.1 | 10.5 | 238 213 |
| 2006 | 247 791 | 109.3 | 11.2 | 253 874 |
| 2007 | 276 242 | 112.4 | 12.6 | 282 821 |
| 2008 | 270 961 | 154.2 | 13.6 | 278 869 |
| 2009 | 275 883 | 172.7 | 14.0 | 284 372 |
| 2010 | 270 663 | 168.4 | 13.2 | 278 821 |
| 2011 | 291 695 | 147.8 | 14.1 | 299 601 |
| 2012 | 304 288 | 155.9 | 9.8 | 311 108 |
| 2013 | 292 768 | 131.5 | 9.9 | 299 000 |
| 2014 | 309 113 | 130.8 | 10.6 | 315 551 |
| 2015 | 329 627 | 82.5 | 12.5 | 335 411 |
| 2016 | 345 140 | 82.3 | 13.0 | 351 075 |
| 2017 | 366 740 | 94.0 | 13.8 | 373 202 |
| 2018 | 359 644 | 94.0 | 12.4 | 365 439 |

**Figure 3.3 $CO_2$ emissions from fuel combustion, 1990-2018**

Energy industry has the highest share in total $CO_2$ emission from fuel combustion in 2018. It is followed by transport, other sectors, and manufacturing industries and construction.

**Figure 3.4 $CO_2$ emissions from fuel combustion by sectors, 1990 and 2018**

**Figure 3.5 $CH_4$ emissions from fuel combustion, 1990-2018**

**Figure 3.6 $N_2O$ emissions from fuel combustion, 1990-2018**

### 3.2.1. Comparison of the sectoral approach with reference approach

The IPCC Reference Approach is a top down inventory based on production, imports, exports, stock change and international bunker consumption of fuels.

2006 IPCC methodology is used for reference approach $CO_2$ estimation. The estimation based on the apparent consumption of fuels in the country. The apparent consumption of primary fuels has been calculated by using the following formula:

**Apparent consumption = Domestic production + imports - exports - change (increase/decrease) in stocks - international bunkers**

Apparent consumption of secondary fuels has been calculated by using the following formula:

**Apparent consumption= imports - exports - change (increase/decrease) in stocks- international bunkers**

The apparent consumption is need to be adjusted for feedstocks, reductants and other non-energy use of fuels. The fossil fuels used for non-energy purposes should be deducted from the apparent consumption in order to avoid double counting in reference approach. (See section 3.2.3 *Feedstocks, Reductants and Other Non-Energy Use of Fuels* )

Domestic production, import, export, stock change and international bunkers have been taken from national energy balance tables for all primary fuels and petroleum products in ktoe unit.

Note that the reference approach emission calculation is dependent on the national energy balance tables and the fuel classification in the national energy balance table is different than CRF fuel classification. Therefore, the fuels in the national energy balance table is allocated into CRF fuel classification according to the table below.

The allocation of fuels into the CRF 1AB category is shown in the table below.

**Table 3.9 Fuel allocation in reference approach**

| Fuel allocated under national energy balance table | Fuel allocated under CRF 1AB sector |
|---|---|
| Hard coal | Coking coal |
| Lignite | Lignite |
| Asphaltite | Sub bitiminous coal |
| Coke | Coke oven coke |
| Coal tar | Coal tar |
| Crude oil | Crude oil |
| Petrocoke | Petroleum coke |
| Fuel oil | Residual fuel oil |
| Diesel | Diesel oil |
| Gasoline | Gasoline |
| LPG | LPG |
| Rafinery gas | Other oil |
| Aviation fuel | Jet kerosene |
| Kerosene | Other kerosene |
| Naphta | Naphta |
| Intermediate products | Other oil |
| Base oils | Other oil |
| White spirit | Other oil |
| Bitumen | Other oil |
| Other petroleum products | Other oil |
| Natural gas | Natural gas |
| Fuel wood | Solid biomass |
| Animal&Vegetable waste | Solid biomass |
| Biofuels | Liquid biomass |

**Table 3.10 $CO_2$ emissions from fuel combustion, 1990-2018**

(kt)

| | Reference Approach | | | | | Sectoral Approach | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Liquid fuels (excluding international bunkers) | Solid fuels (excluding international bunkers) | Gaseous fuels | Other fossil fuels | Total | Liquid fuels (excluding international bunkers) | Solid fuels (excluding international bunkers) | Gaseous fuels | Other fossil fuels | Total |
| 1990 | 66 028 | 63 851 | 5 538 | NO | 135 417 | 59 775 | 63 172 | 6 716 | NO | 129 662 |
| 1991 | 63 928 | 68 970 | 7 090 | NO | 139 989 | 58 433 | 67 539 | 8 265 | NO | 134 236 |
| 1992 | 68 820 | 69 670 | 7 888 | NO | 146 377 | 62 934 | 68 552 | 9 036 | NO | 140 522 |
| 1993 | 79 456 | 64 674 | 8 849 | NO | 152 978 | 72 870 | 63 995 | 10 074 | NO | 146 939 |
| 1994 | 76 788 | 65 631 | 9 582 | NO | 152 001 | 70 321 | 62 993 | 10 585 | NO | 143 899 |
| 1995 | 83 270 | 69 406 | 12 363 | NO | 165 039 | 77 720 | 65 272 | 13 626 | 1 | 156 618 |
| 1996 | 89 069 | 79 907 | 14 681 | NO | 183 657 | 81 746 | 76 505 | 15 918 | 5 | 174 175 |
| 1997 | 88 669 | 89 285 | 18 378 | NO | 196 331 | 81 515 | 84 429 | 19 879 | 9 | 185 832 |
| 1998 | 83 850 | 91 796 | 19 596 | NO | 195 241 | 77 139 | 87 610 | 20 655 | 12 | 185 415 |
| 1999 | 85 127 | 81 524 | 24 329 | NO | 190 980 | 78 484 | 78 236 | 25 848 | 17 | 182 585 |
| 2000 | 91 665 | 94 543 | 28 572 | NO | 214 779 | 82 159 | 92 771 | 29 371 | 42 | 204 343 |
| 2001 | 86 964 | 79 147 | 30 951 | NO | 197 062 | 77 821 | 78 707 | 31 937 | 4 | 188 469 |
| 2002 | 89 278 | 81 489 | 32 934 | NO | 203 702 | 79 708 | 81 652 | 33 875 | 39 | 195 274 |
| 2003 | 90 895 | 92 306 | 40 026 | NO | 223 226 | 81 317 | 85 950 | 42 260 | 11 | 209 538 |
| 2004 | 93 976 | 86 966 | 41 909 | NO | 222 851 | 85 186 | 86 660 | 43 265 | 37 | 215 148 |
| 2005 | 94 669 | 89 723 | 50 823 | NO | 235 215 | 83 332 | 95 196 | 53 664 | 75 | 232 267 |
| 2006 | 88 099 | 104 049 | 59 200 | NO | 251 348 | 81 906 | 104 396 | 61 441 | 48 | 247 791 |
| 2007 | 90 542 | 117 673 | 69 921 | NO | 278 136 | 86 422 | 118 279 | 71 405 | 136 | 276 242 |
| 2008 | 89 110 | 119 216 | 70 129 | NO | 278 455 | 85 180 | 114 783 | 70 824 | 175 | 270 961 |
| 2009 | 77 819 | 123 733 | 68 337 | NO | 269 890 | 82 584 | 122 257 | 70 744 | 299 | 275 883 |
| 2010 | 86 236 | 126 949 | 72 623 | NO | 285 808 | 78 708 | 120 683 | 70 832 | 441 | 270 663 |
| 2011 | 85 800 | 131 104 | 85 643 | NO | 302 546 | 81 391 | 125 204 | 84 554 | 545 | 291 695 |
| 2012 | 88 700 | 136 719 | 84 926 | NO | 310 345 | 87 092 | 131 041 | 85 351 | 803 | 304 288 |
| 2013 | 93 760 | 119 302 | 86 085 | NO | 299 146 | 91 718 | 114 701 | 85 182 | 1 166 | 292 768 |
| 2014 | 93 634 | 129 240 | 92 030 | NO | 314 904 | 96 257 | 119 749 | 91 869 | 1 238 | 309 113 |
| 2015 | 103 507 | 131 830 | 90 528 | NO | 325 839 | 105 439 | 128 006 | 94 370 | 1 812 | 329 627 |
| 2016 | 110 634 | 139 981 | 87 954 | NO | 338 534 | 114 082 | 139 842 | 89 708 | 1 508 | 345 140 |
| 2017 | 115 696 | 153 088 | 101 863 | NO | 370 613 | 116 300 | 145 912 | 102 693 | 1 836 | 366 740 |
| 2018 | 108 902 | 157 464 | 93 420 | NO | 359 786 | 113 524 | 150 431 | 93 478 | 2 211 | 359 644 |

**Figure 3.7 $CO_2$ emissions from fuel combustion, 1990-2018**

**Table 3.11 Comparison of $CO_2$ from fuel combustion between reference and sectoral approach, 1990-2018**

| | Reference approach | | Sectoral approach | | |
|---|---|---|---|---|---|
| Year | Apparent consumption (PJ) | Emissions (kton $CO_2$) | Apparent consumption (PJ) | Emissions (kton $CO_2$) | Difference in emissions (%) |
| 1990 | 1 795 | 135 417 | 1 492 | 129 662 | 4.4 |
| 1991 | 1 826 | 139 989 | 1 537 | 134 236 | 4.3 |
| 1992 | 1 914 | 146 377 | 1 620 | 140 522 | 4.2 |
| 1993 | 2 047 | 152 978 | 1 735 | 146 939 | 4.1 |
| 1994 | 2 007 | 152 001 | 1 699 | 143 899 | 5.6 |
| 1995 | 2 188 | 165 039 | 1 878 | 156 618 | 5.4 |
| 1996 | 2 410 | 183 657 | 2 072 | 174 175 | 5.4 |
| 1997 | 2 562 | 196 331 | 2 212 | 185 832 | 5.6 |
| 1998 | 2 580 | 195 241 | 2 207 | 185 415 | 5.3 |
| 1999 | 2 581 | 190 980 | 2 243 | 182 585 | 4.6 |
| 2000 | 2 891 | 214 779 | 2 506 | 204 343 | 5.0 |
| 2001 | 2 686 | 197 062 | 2 340 | 188 469 | 4.5 |
| 2002 | 2 796 | 203 702 | 2 427 | 195 274 | 4.2 |
| 2003 | 3 043 | 223 226 | 2 640 | 209 538 | 6.4 |
| 2004 | 3 138 | 222 851 | 2 755 | 215 148 | 3.5 |
| 2005 | 3 293 | 235 215 | 2 976 | 232 267 | 1.2 |
| 2006 | 3 601 | 251 348 | 3 200 | 247 791 | 1.3 |
| 2007 | 3 966 | 278 136 | 3 570 | 276 242 | 0.5 |
| 2008 | 3 918 | 278 455 | 3 498 | 270 961 | 2.6 |
| 2009 | 3 804 | 269 890 | 3 518 | 275 883 | -2.3 |
| 2010 | 4 005 | 285 808 | 3 454 | 270 663 | 5.3 |
| 2011 | 4 300 | 302 546 | 3 793 | 291 695 | 3.4 |
| 2012 | 4 404 | 310 345 | 3 951 | 304 288 | 1.7 |
| 2013 | 4 320 | 299 146 | 3 844 | 292 768 | 1.9 |
| 2014 | 4 532 | 314 904 | 4 114 | 309 113 | 1.7 |
| 2015 | 4 750 | 325 839 | 4 385 | 329 627 | -1.6 |
| 2016 | 4 979 | 338 534 | 4 570 | 345 140 | -2.1 |
| 2017 | 5 362 | 370 613 | 4 876 | 366 740 | 1.1 |
| 2018 | 5 237 | 368 315 | 4 739 | 359 644 | 2.4 |

**Explanation of differences:**

While converting to common energy units, the reference approach multiplies the apparent fuel consumption by a single conversion factor. On the other hand, each fuel has different heat content. Sectoral approach uses sector specific heat value provided in the energy balance tables.

In sectoral approach fuel consumption and NCVs of 1A1 category have been collected directly from the end users (from electricity and heat producers, refineries and coke producers). It brings differences between the sectoral and reference approaches since the plant level NCVs is differ from average NCVs used in energy balance tables. Especially for solid fuels and more specifically for the Turkish lignite, such differences in NCVs are causing differences. Since the Turkish lignite is poor quality fuel, its NCV is generally too low from the that of literature lignite. In plant level, data regarding the NCV of lignite

changes in a wide range (from 1000 to 6000 kg/kcal). However, in national balance tables, an average NCV value is about 2200 kcal/kg is used. Based on the quality of lignite used in a specific year, consumption in TJ differs from the national energy balance data. This causes differences in emissions.

**Recalculation:**

There is no recalculation in this sector.

## 3.2.2. International bunker fuels

In consistent with the UNFCCC reporting guidelines, $CO_2$, $CH_4$ and $N_2O$ emissions from international bunker fuels are calculated and reported separately.

### 3.2.2.1. International aviation

The fuel type used in international aviation is jet kerosene. Table 3.13 shows the trend in emissions of $CO_2$, $CH_4$, and $N_2O$ from international aviation between 1990 and 2018.

GHG emissions from international aviation have an increasing trend in consistent with the growth in international aviation sector. $CO_2$ eq. emissions were 12.11 Mt in 2018 while it was 0.56 Mt in 1990.

Emissions from international aviation are calculated using the T1 methodology given in the 2006 IPCC Guidelines. The following equation is used.

$$Emissions = fuel\ consumption * EF$$

According to the 2006 IPCC Guidelines, the Tier 1 method should only be used for aircraft using aviation gasoline, not larger aircraft using jet kerosene however use of a higher tier method is not possible in Turkey because aircraft operational use data are not available.

Energy balance tables were used for AD. To estimate emissions, Turkey applies the default emission factors from the 2006 IPCC Guidelines as follows: $CO_2$ (71500 kg/TJ), $CH_4$ (0.5 kg/TJ) and $N_2O$ (2 kg/TJ).

**Figure 3.8 GHG emissions from international aviation, 1990-2018**

**Table 3.12 Emissions and fuel for international aviation, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq (kt) | Aviation bunkers (TJ) |
|---|---|---|---|---|---|
| 1990 | 552 | 0.004 | 0.02 | 556 | 7 718 |
| 1991 | 716 | 0.005 | 0.02 | 722 | 10 011 |
| 1992 | 804 | 0.006 | 0.02 | 811 | 11 246 |
| 1993 | 977 | 0.007 | 0.03 | 986 | 13 671 |
| 1994 | 788 | 0.006 | 0.02 | 795 | 11 025 |
| 1995 | 807 | 0.006 | 0.02 | 814 | 11 290 |
| 1996 | 1 003 | 0.007 | 0.03 | 1 011 | 14 024 |
| 1997 | 1 368 | 0.010 | 0.04 | 1 380 | 19 139 |
| 1998 | 1 523 | 0.011 | 0.04 | 1 536 | 21 300 |
| 1999 | 1 514 | 0.011 | 0.04 | 1 526 | 21 168 |
| 2000 | 1 599 | 0.011 | 0.04 | 1 612 | 22 359 |
| 2001 | 1 592 | 0.011 | 0.04 | 1 606 | 22 271 |
| 2002 | 2 649 | 0.019 | 0.07 | 2 671 | 37 044 |
| 2003 | 2 762 | 0.019 | 0.08 | 2 786 | 38 632 |
| 2004 | 2 977 | 0.021 | 0.08 | 3 002 | 41 630 |
| 2005 | 3 330 | 0.023 | 0.09 | 3 358 | 46 570 |
| 2006 | 3 014 | 0.021 | 0.08 | 3 040 | 42 160 |
| 2007 | 3 731 | 0.026 | 0.10 | 3 762 | 52 177 |
| 2008 | 4 991 | 0.035 | 0.14 | 5 034 | 69 810 |
| 2009 | 5 255 | 0.037 | 0.15 | 5 299 | 73 493 |
| 2010 | 5 858 | 0.041 | 0.16 | 5 908 | 81 937 |
| 2011 | 6 769 | 0.047 | 0.19 | 6 827 | 94 671 |
| 2012 | 7 684 | 0.054 | 0.21 | 7 750 | 107 473 |
| 2013 | 8 661 | 0.061 | 0.24 | 8 734 | 121 129 |
| 2014 | 9 922 | 0.069 | 0.28 | 10 007 | 138 775 |
| 2015 | 11 085 | 0.078 | 0.31 | 11 180 | 155 037 |
| 2016 | 10 630 | 0.074 | 0.30 | 10 720 | 148 668 |
| 2017 | 11 015 | 0.077 | 0.31 | 11 109 | 154 053 |
| 2018 | 12 006 | 0.084 | 0.34 | 12 108 | 167 911 |

### 3.2.2.2. International navigation

The fuel type used in international navigation is diesel oil and residual fuel oil. Table 3.14 shows the trend in emissions of $CO_2$, $CH_4$ and $N_2O$ from international navigation between 1990 and 2018.

GHG emissions from international navigation have an increasing trend corresponding to the growth in the international navigation sector. $CO_2$ emissions were 3.1 Mt in 2018 while it was 0.4 Mt in 1990.

Emissions from international navigation were calculated using the T1 and T2 methodology given in 2006 IPCC Guidelines. Country specific carbon content is used for $CO_2$ emission estimation. 2006 IPCC default EFs are used for $CH_4$ and $N_2O$ emissions. The following equation is used. Activity data is taken from national energy balance tables.

$$Emissions = \sum Fuel\ consumed_{ab} * EF_{ab}$$

Where:

a = fuel type (residual fuel oil and gas diesel oil)

b = water-borne navigation type (the type of vessel b is ignored at Tier 1)

Energy balance tables were used for AD. Country specific carbon content is used for $CO_2$ emission estimation. To estimate $CH_4$ and $N_2O$ emissions, Turkey applies the default emission factors from the 2006 IPCC Guidelines as follows: $CH_4$ (7 kg/TJ) and $N_2O$ (2 kg/TJ).

**Figure 3.9 GHG emissions from international navigation, 1990-2018**

**Table 3.13 Emissions and fuel for international navigation, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Navigation bunkers (TJ) |
|---|---|---|---|---|---|
| 1990 | 379 | 0.035 | 0.01 | 383 | 5 035 |
| 1991 | 423 | 0.039 | 0.01 | 428 | 5 622 |
| 1992 | 347 | 0.032 | 0.01 | 351 | 4 626 |
| 1993 | 313 | 0.029 | 0.01 | 316 | 4 148 |
| 1994 | 351 | 0.033 | 0.01 | 354 | 4 656 |
| 1995 | 587 | 0.055 | 0.02 | 593 | 7 819 |
| 1996 | 395 | 0.037 | 0.01 | 399 | 5 248 |
| 1997 | 502 | 0.047 | 0.01 | 507 | 6 658 |
| 1998 | 509 | 0.047 | 0.01 | 514 | 6 689 |
| 1999 | 894 | 0.083 | 0.02 | 903 | 11 810 |
| 2000 | 1 279 | 0.118 | 0.03 | 1 292 | 16 861 |
| 2001 | 749 | 0.069 | 0.02 | 756 | 9 848 |
| 2002 | 1 690 | 0.156 | 0.04 | 1 707 | 22 334 |
| 2003 | 1 964 | 0.183 | 0.05 | 1 984 | 26 127 |
| 2004 | 3 168 | 0.294 | 0.08 | 3 200 | 41 988 |
| 2005 | 3 376 | 0.312 | 0.09 | 3 411 | 44 586 |
| 2006 | 3 127 | 0.287 | 0.08 | 3 159 | 41 059 |
| 2007 | 2 355 | 0.212 | 0.06 | 2 379 | 30 323 |
| 2008 | 2 325 | 0.211 | 0.06 | 2 348 | 30 114 |
| 2009 | 2 854 | 0.257 | 0.07 | 2 882 | 36 737 |
| 2010 | 2 407 | 0.217 | 0.06 | 2 431 | 31 058 |
| 2011 | 1 951 | 0.176 | 0.05 | 1 971 | 25 160 |
| 2012 | 2 618 | 0.237 | 0.07 | 2 645 | 33 786 |
| 2013 | 2 892 | 0.261 | 0.07 | 2 921 | 37 316 |
| 2014 | 3 260 | 0.294 | 0.08 | 3 292 | 41 958 |
| 2015 | 2 742 | 0.248 | 0.07 | 2 769 | 35 358 |
| 2016 | 3 006 | 0.271 | 0.08 | 3 036 | 38 654 |
| 2017 | 2 871 | 0.262 | 0.08 | 2 900 | 37 487 |
| 2018 | 3 101 | 0.284 | 0.08 | 3 132 | 40 520 |

### Recalculations:

There is no recalculation for this category.

### 3.2.3. Feedstocks, Reductants and other non-energy use of fuels

In accordance with the 2006 IPCC Guidelines, AD and emissions associated with the non-energy use of fuels are not reported within the fuel combustion subsector.

The table below summarize reporting of carbon stored and emissions related to use of feedstock, reductants and other non-energy use of fuels.

**Table 3.14 Summary table for use of feedstock, reductants and other non energy use of fuels**

| Use of fuel | Reported in inventory | Data Source |
|---|---|---|
| Reductant for ferroalloy production | Emissions in 2.C.2; in RA subtracted from coke | Plant specific |
| Reductant for carbide production | Emissions is 2.B.5; in RA subtracted from coke | Plant specific |
| Reductants for steel production in Electric Arc Furnaces | Emissions in 2.C.1; in RA subtracted from coke oven coke and natural gas | Estimated from EAF primary steel production data |
| Reductants for steel production in integrated iron and steel plants | Emissions is 2.C.1; in RA subtracted from coking coal | Plant specific |
| Feedstock for ammonia production | Emissions in 2.B.2; in RA subtracted from natural gas | Plant specific |
| Feedstock for petrochemical industry | Carbon stored, in RA subtracted from naphta | National energy balance table |
| Use of lubricants | Emissions in2.D.1; in RA subtracted from other oil | National energy balance table (Aggregated under other oil) |
| Use of parrafin and wax | Emissions in 2.D.1; in RA subtracted from other oil | National energy balance table (Aggregated under other oil) |
| Use of bitumen for road paving, asphalt roofing etc. | Carbon stored, in RA subtracted from other oil | National energy balance table (Aggregated under other oil) |
| Refinery feedstocks | Carbon stored, in RA subtracted from other oil | National energy balance table (Aggregated under other oil) |

Fossil fuels are used in integrated iron and steel plants for reducing iron ore into iron metal. The reduction process causes $CO_2$ emissions. These emissions are reported under IPPU category. The amount of carbon (fossil fuel originated, not limestone etc.) reported in the IPPU is converted into the amount of coking coal and it is subtracted from the reference approach.

In the national energy balance tables, feedstock and non-energy use of fuels are given separately and those consumptions are not included in fuel consumptions. Naphtha is given as feedstock in the national energy balance tables. Fuels used for non-energy purposes are lubricants, bitumen, solvents and rafinery feedstocks. But they were not given separately in the national energy balance tables till 2015. They were given as aggregated form under "other petroleum products".

Emissions from lubricants and paraffin-wax use are included under 2.D-non-energy products from fuels and solvent use category. However, bitumen is used for road paving or asphalt roofing purposes and carbon is stored in the products it is not released. Refinery feedstock is used in the refining industry and is transformed into one or more components and/or finished products. Naphtha is used as feedstock for petrochemical industry.

**Recalculation:**

There is no recalculation in this sector.

## 3.2.4. Energy industries (Category 1.A.1)

**Source Category Description:**

This source category includes the emission from the public electricity and heat production, petroleum refining and manufacture of solid fuels in Turkey. This category is one of the main emission sources in Turkey. The share of GHG emissions as $CO_2$ eq**.** from energy industries in total fuel combustion was 43.4% in 2018 while it was 28% in 1990. The source category 1.A.1 is a key category in terms of emission level and emission trend of $CO_2$ from liquid, solid and gaseous fuels in 2018.

**Table 3.15 GHG emissions from energy industries, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) |
|---|---|---|---|---|---|
| 1990 | 37 130 | 0.4 | 0.4 | 37 253 | 395 856 |
| 1991 | 38 663 | 0.5 | 0.4 | 38 791 | 411 244 |
| 1992 | 43 178 | 0.5 | 0.5 | 43 324 | 456 727 |
| 1993 | 42 609 | 0.5 | 0.4 | 42 752 | 455 875 |
| 1994 | 48 892 | 0.6 | 0.5 | 49 059 | 519 646 |
| 1995 | 50 298 | 0.6 | 0.5 | 50 465 | 545 725 |
| 1996 | 54 254 | 0.6 | 0.6 | 54 437 | 584 018 |
| 1997 | 59 383 | 0.7 | 0.6 | 59 581 | 647 072 |
| 1998 | 64 948 | 0.8 | 0.7 | 65 164 | 712 882 |
| 1999 | 70 137 | 0.9 | 0.7 | 70 360 | 802 036 |
| 2000 | 77 503 | 1.0 | 0.7 | 77 743 | 906 993 |
| 2001 | 79 779 | 1.0 | 0.7 | 80 022 | 942 482 |
| 2002 | 73 926 | 1.0 | 0.6 | 74 138 | 891 876 |
| 2003 | 73 831 | 1.0 | 1.7 | 74 371 | 923 807 |
| 2004 | 74 883 | 1.0 | 2.1 | 75 539 | 932 120 |
| 2005 | 89 666 | 1.2 | 2.6 | 90 458 | 1 105 479 |
| 2006 | 95 240 | 1.3 | 2.9 | 96 129 | 1 173 383 |
| 2007 | 112 397 | 1.5 | 3.8 | 113 570 | 1 392 862 |
| 2008 | 117 705 | 1.6 | 4.0 | 118 939 | 1 465 366 |
| 2009 | 117 894 | 1.7 | 4.5 | 119 280 | 1 467 055 |
| 2010 | 112 091 | 1.7 | 4.0 | 113 324 | 1 399 222 |
| 2011 | 123 669 | 1.9 | 4.2 | 124 975 | 1 539 469 |
| 2012 | 124 753 | 1.9 | 3.8 | 125 944 | 1 575 464 |
| 2013 | 119 519 | 1.8 | 4.1 | 120 773 | 1 509 951 |
| 2014 | 130 128 | 1.9 | 4.4 | 131 474 | 1 681 459 |
| 2015 | 133 503 | 1.9 | 3.9 | 134 702 | 1 676 362 |
| 2016 | 142 679 | 2.0 | 4.1 | 143 963 | 1 753 313 |
| 2017 | 153 557 | 2.1 | 4.6 | 154 971 | 1 914 595 |
| 2018 | 157 443 | 2.0 | 3.3 | 158 490 | 1 900 247 |

### Methodological Issues:

2006 IPCC Guidelines T2 and T3 approaches were used for emission calculation in energy industries. The emissions from public electricity and heat production (1.A.1.a) are calculated on the basis of plant specific fuel consumption and NCVs with country specific carbon contents of fuels. For petroleum refining sector, fuel data, NCV and carbon content of fuels were compiled directly from the refineries. For manufacture of solid fuels (1.A.1.c) category, plant specific AD and carbon content were used in the emission estimation.

Emissions from CRF category 1.A.1.a, have been estimated by the MENR by using 2006 IPCC T2, T3 approaches. Plant-specific NCVs were used to calculate heat values that led to emissions. Plant level fuel consumption and NCVs of fuels are received from Turkish Electricity Transmission Company (TEİAŞ-authority for Turkish electricity transmission). Carbon contents of fuels are calculated using fuel analysis reports and oxidation rates are calculated using ash and slag analysis reports for solid fuels, and stack gas analysis reports for liquid and gaseous fuels. $CO_2$ emissions from liquid, solid and gaseous fuels used in public electricity and heat production (1.A.1.a) are calculated using country specific carbon content of fuels and oxidation rates. For biomass and other fossil fuels on the other hand, default carbon contents and oxidation rates were used given in the 2006 IPCC Guidelines. Activity data of $CH_4$ and $N_2O$ emissions from CRF category 1A1a, have been estimated by using plant specific fuel consumption and NCVs. For the years 2000-2016 technology information of power plants were obtained. According to type of technology, using 2006 IPCC Guidelines for National Greenhouse Gas Inventories, emission factors were chosen in order for $CH_4$ and $N_2O$ to be estimated with Tier 3.

Emissions from petroleum refining (CRF 1.A.1.b) were calculated according to 2006 IPCC T2 approach by TurkStat. Fuel consumption, NCVs and carbon content of fuels were compiled directly from refineries. $CO_2$ emissions from 1.A.1.b were calculated by using average carbon contents of fuels used in the refineries with IPCC default oxidation rates. $CH_4$ and $N_2O$ emissions from CRF category 1.A.1.b, have been estimated by using refineries total fuel consumption and average NCVs for refineries with IPCC default EFs.

Emissions from manufacture of solid fuels (CRF 1.A.1.c) were calculated according to 2006 IPCC T2, T3 approaches by TurkStat. Coke production in integrated iron and steel production plants have been considered in this category. Plant specific fuel consumption, NCVs and carbon content of fuels were compiled from each plant. $CO_2$ emissions from 1.A.1.c were calculated by using plant specific AD, carbon contents of fuels and IPCC default oxidation rates. $CH_4$ and $N_2O$ emissions from CRF category 1.A.1.c, have been estimated by using plant specific fuel consumption and NCVs and IPCC default EFs.

**Recalculation:**

There is no recalculation in this sector.

### 3.2.4.1. Public electricity and heat production (Category 1.A.1.a)

#### Source Category Description:

Public electricity and heat production category includes electricity and heat production of all electricity generation installations in operation including auto producers. Auto producers are the facilities that produce electricity that they use for their own purposes. Their AD (Activity Data) for electricity production and sold heat are taken under 1.A.1.a. Unsold heat, namely the heat they use for industry purpose, on the other hand, is taken under the related industry subcategory they belong to in order to avoid double counting for the whole time series. For 1.A.1.a sector plant specific AD are gathered from Turkish Electricity Transmission Company (TEİAŞ).

Total installed capacity reached to 88,551 MW with 3.9% increase from the previous year and more than 5.4 times higher than 1990 values. The total gross electricity consumption has increased by 2.5% in 2018 compared to the previous year. In the year 2018, gross consumption was 304,167 GWh meanwhile in 2017 this figure realized as 296,702 GWh. Above mentioned installed capacities and consumption amounts belong to electricity production companies and auto producers as well. In 2018, natural gas had high share of 30.34% in all electricity production, which was followed by hydro and geothermal (22.10%), other bituminous coal (22.36%), Turkish lignite (14.79%), other renewable (10.29%) and oil (0.11%). From 2017 to 2018, electricity production from hydropower plants increased by 3%. Amount of electricity production from Turkish lignite has increased from 40.69 TWh to 45.09 TWh, from 56.78 TWh to 68.16 TWh for other bituminous coal respectively. On the other hand, electricity production from natural gas decreased from 110.49 TWh to 92.48 TWh.

In 2018 electricity production from fossil fueled thermal power plants has accounted for 206.06 TWh of a total of 304.80 TWh production whilst in 2017 electricity production from fossil fueled thermal power plants had accounted for 209.17 TWh of a total of 297.28 TWh production. Fossil fueled thermal share in electricity production decreased from 70.36% in 2017 to 67.60% in 2018.

**Figure 3.10 Energy mix of category 1.A.1.a, 1990-2018[1]**

There was an increase in wind installed capacity from 6,516 MW in 2017 to 7,005 MW in the year 2018. Renewable Law which came into force in 2005 later revised in 2011 provided some supporting mechanism for purchasing electricity from solar, biomass, geothermal, wind and hydraulic energy. In the year 2018 solar power plants installed capacity raised to 5,063 MW. The role of voluntary carbon market is important to mention, as many of the wind projects in the country generate and sell the voluntary carbon credits.

Electricity generation from animal and yard waste has increased by 21.9% compared to the previous year, reaching to 811 MW of installed power, generating 3,623 GWh of power in 2018.

In 2018, Turkey's Total Primary Energy Supply (TPES) was 6 015 005.90 TJ, a 1.13% decrease compared to 2017. Oil had a share of 1 754 833.36 TJ while hard coal and gas accounted for 1 033 258.81 TJ and 1 723 737.60 TJ respectively.

[1]Electricity Statistics, TEİAŞ (https://www.teias.gov.tr/en/electricity-statistictsin-turkish)

**Figure 3.11 Electricity generation and shares by energy resources, 2017 - 2018[2]**

**Figure 3.12 Electricity generation and shares by energy resources, 1990 - 2018[3]**

Primary energy (domestic) production was 1 661 108.45 TJ in 2018 and provided 28% of overall energy supply. The share of import in TPES decreased from 86% in 2017 to 81% in 2018.

[2]Electricity Statistics, TEİAŞ (https://www.teias.gov.tr/en/electricity-statistictsin-turkish)
[3]Electricity Statistics, TEİAŞ (https://www.teias.gov.tr/en/electricity-statistictsin-turkish)

The production of solid fossil fuels, excluding animal & yard waste, has increased from 631 638.2 TJ in 2017 to 692 802.81 TJ in 2018. The main domestic energy source remains as Turkish lignite with a production increased from 71.46 Mt in 2017 to 81.08 Mt in 2018 which represented a rise by about %13.47.

The share of GHG emissions from public electricity and heat production in total fuel combustion was 41.0% in 2018 while it was 24.4% in 1990. According to Table 3.16, fuel consumption decreased from 1 804 038 TJ in 2017 to 1 791 670 TJ in 2018 when the $CO_2$ emissions increased from 144 814 kt in 2017 to 148 992 kt in 2018. In other words, the decrease in fuel consumption was 0.7% and increase in $CO_2$ emissions was 2.9%. The main reason is decreasing of natural gas share in electricity generation in 2018 (30.3%) compared to previous year (37.2%).

**Table 3.16 Emissions from category 1A1a, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) |
|---|---|---|---|---|---|
| 1990 | 32 823 | 0.3 | 0.4 | 32 938 | 346 707 |
| 1991 | 34 429 | 0.4 | 0.4 | 34 550 | 362 934 |
| 1992 | 39 047 | 0.4 | 0.4 | 39 186 | 408 249 |
| 1993 | 38 255 | 0.4 | 0.4 | 38 390 | 403 148 |
| 1994 | 44 562 | 0.5 | 0.5 | 44 721 | 466 134 |
| 1995 | 45 860 | 0.5 | 0.5 | 46 020 | 490 230 |
| 1996 | 49 744 | 0.5 | 0.5 | 49 919 | 529 408 |
| 1997 | 54 810 | 0.6 | 0.6 | 55 000 | 590 895 |
| 1998 | 60 336 | 0.7 | 0.6 | 60 544 | 656 466 |
| 1999 | 65 778 | 0.8 | 0.7 | 65 993 | 749 301 |
| 2000 | 73 139 | 0.9 | 0.7 | 73 371 | 854 300 |
| 2001 | 75 351 | 0.9 | 0.7 | 75 586 | 888 392 |
| 2002 | 69 374 | 0.8 | 0.6 | 69 578 | 834 375 |
| 2003 | 68 970 | 0.9 | 1.7 | 69 501 | 862 965 |
| 2004 | 69 840 | 0.9 | 2.1 | 70 485 | 866 064 |
| 2005 | 84 623 | 1.1 | 2.5 | 85 407 | 1 036 864 |
| 2006 | 90 115 | 1.2 | 2.9 | 90 994 | 1 103 265 |
| 2007 | 107 431 | 1.4 | 3.8 | 108 595 | 1 323 995 |
| 2008 | 112 408 | 1.5 | 4.0 | 113 633 | 1 389 232 |
| 2009 | 113 842 | 1.6 | 4.5 | 115 222 | 1 413 335 |
| 2010 | 107 664 | 1.6 | 4.0 | 108 892 | 1 344 379 |
| 2011 | 118 730 | 1.8 | 4.2 | 120 031 | 1 478 115 |
| 2012 | 119 702 | 1.8 | 3.8 | 120 889 | 1 512 807 |
| 2013 | 114 861 | 1.7 | 4.0 | 116 110 | 1 451 358 |
| 2014 | 125 665 | 1.8 | 4.3 | 127 006 | 1 624 731 |
| 2015 | 126 767 | 1.8 | 3.8 | 127 958 | 1 591 475 |
| 2016 | 134 280 | 1.9 | 4.1 | 135 554 | 1 644 763 |
| 2017 | 144 814 | 1.9 | 4.6 | 146 220 | 1 804 038 |
| 2018 | 148 992 | 1.9 | 3.3 | 150 032 | 1 791 670 |

## Methodological Issues:

### Activity Data

The plant specific activity data for the whole time series is obtained from Turkish Electricity Transmission Company (TEİAŞ) in a compiled form. After the completion of data obtaining, sector experts checked whether there were data errors or omissions, and then data compared with fuel specific default values from IPCC guidelines and also literature. Cross checks including fuel capacity factor controls, and examining outliers give some opinion about data consistency. Suspicious data are corrected by getting contact with Turkish Electricity Transmission Company (TEİAŞ).

As soon as the sector experts are assured about data reliability, data entry to the overall calculation table begins. After entering data of every single plant that produced electricity in the related year, heat content of fuels is calculated with plant specific data obtained from Turkish Electricity Transmission Company (TEİAŞ). In order to obtain plant specific activity data, the amount of feedstock fuel used is multiplied by plant specific NCVs to get heat values in terms of TJ. Average NCVs are given in the Table 3.17.

**Table 3.17 Average NCVs of fuels used in category 1.A.1.a (TJ/kt)**

| Fuel Type | Weighted average | Default |
|---|---|---|
| Sub-Bituminous Coal | 14.56 | 18.90 |
| Natural gas | 52.34 | 48.00 |
| Residual Fuel Oil | 45.54 | 40.40 |
| Other bituminous coal | 24.01 | 25.80 |
| Turkish lignite | 6.70 | 11.90 |
| Gas\Diesel Oil | 43.12 | 43.00 |

The multipliers of EF, namely carbon content and oxidation rates were calculated. For Turkish lignite, sub-bituminous and other bituminous coal, ultimate analysis results, which were obtained from coal-fired power plants, were used to calculate carbon content of the related coal types. For liquid fuels the same procedure was applied through residual fuel oil characteristics and mass percentage of carbon. For natural gas, volumetric fractions of gas concentrations were obtained through gas chromatography analysis from Petroleum Pipeline Company (BOTAŞ). Using density of the gases and some stoichiometry carbon mass amount of each gas compounds were calculated and summed up to reach an overall carbon amount. Oxidation rate of solid fuels was calculated by using the mass percentage of carbon in ash-slag analysis reports obtained from coal firing plants. For gaseous fuels, measured CO concentrations in the stack gas were used in order to calculate mass percentage of the unoxidized carbon and then oxidation rate of the related fuel. In order to calculate the oxidation rate of gaseous fuels (natural gas), CO concentrations measured in the stack gas of the related plants were obtained from the Ministry of

Environment and Urbanization. Some of the analysis reports and calculation steps were shared in Annex 3. $CO_2$ EFs used for source category 1.A.1.a were listed in Table 3.18 for whole time series on fuel basis.

For $CH_4$ and $N_2O$ emissions starting from the year 2000, plant specific technology classification information were obtained from Turkish Electricity Transmission Company (TEİAŞ). Using *Table 2.6: Utility Source Emission Factors* from Stationary Combustion Chapter of Guideline, Tier 3 EFs for $CH_4$ and $N_2O$ were chosen.

EFs for $CH_4$ and $N_2O$ were listed in Table 3.19 for whole time series on fuel basis.

**Table 3.18 $CO_2$ emission factors used for source category 1.A.1.a, 1990-2018**

(t/TJ)

| Year | Turkish Lignite | Sub-Bituminous Coal | Other Bituminous Coal | Natural Gas | Residual Fuel Oil | Diesel Oil | LPG | Biogas | Industrial Waste | Wood-wood waste | Coke Oven Gas | Black Liquor | Blast Furnace Gas | Petroleum Coke | Oxygen Steel Furnace Gas | Coal Tar | Refinery Gas |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 114.16 | 93.37 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1991 | 114.01 | 101.38 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1992 | 113.85 | 101.35 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1993 | 113.70 | 100.54 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1994 | 113.54 | 99.12 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1995 | 113.39 | 102.17 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1996 | 113.23 | 102.50 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1997 | 113.08 | 103.34 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1998 | 112.92 | 102.81 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 1999 | 112.77 | 93.39 | NO | 58.23 | 76.97 | 72.28 | 63.07 | NO | NO | NO | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2000 | 110.05 | 95.52 | 88.62 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2001 | 110.58 | 99.28 | 88.62 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2002 | 111.30 | 96.27 | 88.62 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2003 | 112.00 | 100.90 | 79.88 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2004 | 112.72 | 90.34 | 84.02 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2005 | 113.50 | 94.23 | 85.24 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2006 | 114.18 | 88.71 | 90.07 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2007 | 113.62 | 88.52 | 91.17 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2008 | 112.51 | 93.35 | 83.29 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2009 | 111.39 | 96.03 | 90.35 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2010 | 110.26 | 98.56 | 90.01 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2011 | 109.48 | 95.10 | 89.11 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2012 | 109.29 | 96.65 | 88.89 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2013 | 109.09 | 96.18 | 93.57 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2014 | 107.63 | 93.15 | 87.70 | 58.23 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2015 | 107.63 | 92.38 | 92.64 | 58.66 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2016 | 107.41 | 85.32 | 91.37 | 56.04 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2017 | 107.24 | 94.50 | 91.55 | 56.02 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.46 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |
| 2018 | 107.55 | 94.12 | 92.75 | 55.74 | 76.97 | 72.28 | 63.07 | 54.63 | 143.00 | 111.83 | 37.35 | 95.33 | 259.60 | 97.53 | 181.87 | 80.67 | 57.57 |

**Table 3.19 $CH_4$ and $N_2O$ emission factors used for source category 1.A.1.a**

(kg/TJ)

| Fuel Types | $CH_4$ | $N_2O$ |
|---|---|---|
| **Liquid Fuels** | | |
| **Fuel Oil** | | |
| Steam | 0.8 | 0.3 |
| Internal Combustion | 0.8 | 0.3 |
| Combined Heat | 0.8 | 0.3 |
| **Liquid Fuels** | | |
| **Diesel Oil, Naphtha** | | |
| Steam | 0.9 | 0.4 |
| Internal Combustion | 0.9 | 0.4 |
| Combined Heat | 0.9 | 0.4 |
| **Solid Fuels** | | |
| **Turkish Lignite and Sub-Bituminous and Other Bituminous Coal** | | |
| Dry bottom, wall fired | 0.7 | 0.5 |
| Fluidised Bed | 1 | 61 |
| Lignite (other type of technology) | 0.7 | 1.4 |
| Sub-Bituminous and Coking Coal | 0.7 | 1.4 |
| **Natural Gas** | | |
| Boiler | 4 | 1 |
| Gas Engine | 4 | 1 |
| Gas Turbine | 4 | 1 |
| Internal Combustion | 4 | 1 |
| Combined Heat | 1 | 3 |
| **Other Fuels** | | |
| Coke Oven Gas | 1 | 0.1 |
| Blast Furnace Gas | 1 | 0.1 |
| Oxygen Steel Furnace Gas | 1 | 0.1 |
| Coal Tar | 1 | 1.5 |
| LPG | 1 | 0.1 |
| Refinery Gas | 1 | 0.1 |
| Petroleum Coke | 3 | 0.6 |
| Other Petroleum Products | 3 | 0.6 |
| Black Liquor | 3 | 2 |
| Industrial Waste | 30 | 4 |
| **Biomass** | | |
| Biogas | 1 | 1 |
| Wood waste | 11 | 7 |

### Comparability and Accuracy through Nomenclature Change:

NCV of Turkish lignite differs significantly with that of Energy Statistics Handbook and general fuel literature. It is even lower the lowest value of lignite in all reports of the parties Parties. Analysis reports

support this NCV data of Turkish lignite. Its average carbon content in 2018 is 30.50 kg/GJ, approaches the upper limit of 2006 IPCC Guidelines (31.3 kg/GJ). In order to recategorise our local lignite, we renamed it as "Turkish Lignite" to separate it from literature lignite and therefore avoid misleading comparisons.

### Carbon Capture and Storage in 1.A.1.a, if applicable

$CO_2$ capture from flue gases and $CO_2$ storage is not occurring in Turkey, except pilot scaled research fields.

### Implied Emission Factor (IEF) Trends and Comments

IEFs were examined in the following table to see time series consistency for solid, liquid, gaseous fuels and biomass respectively.

**Table 3.20 IEFs of fuels used for category 1.A.1.a, 1990-2018**

**(t/TJ)**

| | $CO_2$ | | | | | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Solid Fuels** | | **Liquid Fuels** | | **Gaseous Fuels** | | **Biomass** | | **Biomass** | |
| **Years** | CHP | Electricity Generation | CHP | Electricity Generation | CHP | Electricity Generation | CHP | Electricity Generation | CHP | Electricity Generation |
| 1990 | - | 113.41 | - | 76.88 | 58.23 | 58.23 | - | - | - | - |
| 1991 | - | 113.42 | - | 76.89 | 58.23 | 58.23 | - | - | - | - |
| 1992 | - | 113.01 | - | 76.93 | 58.23 | 58.23 | - | - | - | - |
| 1993 | - | 112.79 | - | 76.93 | 58.23 | 58.23 | - | - | - | - |
| 1994 | - | 112.62 | - | 76.93 | 58.23 | 58.23 | - | - | - | - |
| 1995 | - | 112.78 | - | 76.74 | 58.23 | 58.23 | - | - | - | - |
| 1996 | - | 112.60 | - | 76.70 | 58.23 | 58.23 | - | - | - | - |
| 1997 | - | 112.43 | - | 76.52 | 58.23 | 58.23 | - | - | - | - |
| 1998 | - | 112.28 | - | 76.13 | 58.23 | 58.23 | - | - | - | - |
| 1999 | - | 111.56 | - | 75.66 | 58.23 | 58.23 | - | - | - | - |
| 2000 | 120.03 | 110.51 | 74.03 | 75.55 | 58.23 | 58.23 | 4.80 | 2.92 | 2.13 | 1.65 |
| 2001 | 117.56 | 111.08 | 65.95 | 74.80 | 58.23 | 58.23 | 4.84 | 3.78 | 2.14 | 1.48 |
| 2002 | 123.56 | 112.39 | 75.38 | 76.50 | 58.23 | 58.23 | 4.80 | 4.73 | 2.13 | 1.59 |
| 2003 | 128.20 | 109.22 | 75.75 | 76.57 | 58.23 | 58.23 | 3.13 | 2.57 | 2.08 | 1.85 |
| 2004 | 130.18 | 108.85 | 75.99 | 76.48 | 58.23 | 58.23 | 3.00 | 1.89 | 2.00 | 1.44 |
| 2005 | 125.53 | 109.76 | 76.05 | 76.09 | 58.23 | 58.23 | 2.37 | 1.11 | 1.68 | 1.06 |
| 2006 | 140.06 | 110.54 | 76.95 | 75.96 | 58.23 | 58.23 | 2.61 | 1.44 | 1.81 | 1.22 |
| 2007 | 137.25 | 110.10 | 76.96 | 76.05 | 58.23 | 58.23 | 2.28 | 1.37 | 1.64 | 1.18 |
| 2008 | 136.91 | 107.98 | 76.94 | 76.05 | 58.23 | 58.23 | 2.83 | 1.41 | 2.02 | 1.22 |
| 2009 | 138.78 | 109.37 | 73.76 | 76.07 | 58.23 | 58.23 | 3.52 | 1.33 | 2.44 | 1.18 |
| 2010 | 130.35 | 107.83 | 70.62 | 76.10 | 58.23 | 58.23 | 4.57 | 1.44 | 3.06 | 1.25 |
| 2011 | 134.30 | 105.10 | 69.63 | 75.41 | 58.23 | 58.23 | 2.41 | 1.08 | 1.82 | 1.05 |
| 2012 | 132.06 | 102.89 | 60.18 | 73.23 | 58.23 | 58.23 | 1.11 | 1.10 | 1.03 | 1.05 |
| 2013 | 132.06 | 105.23 | 61.41 | 73.84 | 58.23 | 58.23 | 1.54 | 1.10 | 1.31 | 1.05 |
| 2014 | 111.14 | 100.49 | 64.07 | 75.79 | 58.23 | 58.23 | 2.29 | 1.09 | 1.74 | 1.05 |
| 2015 | 105.74 | 101.35 | 69.34 | 73.52 | 58.66 | 58.66 | 1.40 | 1.07 | 1.23 | 1.04 |
| 2016 | 120.84 | 101.98 | 76.97 | 74.00 | 56.04 | 56.04 | 1.38 | 1.04 | 1.22 | 1.02 |
| 2017 | 107.77 | 102.26 | 76.97 | 73.24 | 56.02 | 56.02 | 1.25 | 1.02 | 1.14 | 1.01 |
| 2018 | 119.49 | 101.49 | 76.97 | 76.24 | 55.75 | 55.75 | 1.76 | 1.31 | 1.45 | 1.19 |

IEFs of $CO_2$ ranges from 101 to 146 t/TJ. It is mainly because of local Turkish lignite and its share in solid fuels. Different from literature lignite of statistics manual, Turkey's lignite has a very low NCV, about one fifth of that of literature. Also its share in the solid fuels affects the overall IEF causing a dramatic rise and fall like its trend through the years 2001-2014 for 1.A.1.a.i.

IEFs of gaseous fuels do not change considerably over time. IEFs of $CO_2$ ranges from 56 to 58 t $CO_2$/TJ. The reason for this change is the use of more gas chromatography results for analysis. After 2000 the values of CHP Generation are the same as Electricity Generation.

Fluctuations in IEFs, especially declines are mainly owing to the increasing share of biogas. Rises in the trend, however, due to share of black liquor. "Other Fossil Fuels" node is used for industrial wastes data reporting that consist of clinic and hazardous wastes.

Emission estimation with T2, T3 approach using plant specific data are compared with the T1 emission estimation using fuel data from national energy balance tables. Comparison with the T1 emission estimation results is given in Table 3.21.

**Table 3.21 Comparison of GHG emissions from 1.A.1.a category ,1990-2018**

| | GHG emissions with plant specific data | | GHG emissions with national energy balance data | | Difference | |
|---|---|---|---|---|---|---|
| Year | GHG Emission (kt $CO_2$ eq.) | Fuel consumption (TJ) | GHG Emission (kt $CO_2$ eq.) | Fuel consumption (TJ) | GHG emission (kt $CO_2$ eq.) | Fuel consumption (TJ) |
| 1990 | 32 938 | 346 707 | 35 018 | 360 733 | -2 080 | -14 026 |
| 1991 | 34 550 | 362 934 | 36 549 | 374 744 | -1 999 | -11 810 |
| 1992 | 39 186 | 408 249 | 41 241 | 423 770 | -2 055 | -15 521 |
| 1993 | 38 390 | 403 148 | 40 732 | 418 681 | -2 342 | -15 533 |
| 1994 | 44 721 | 466 134 | 47 185 | 484 105 | -2 464 | -17 971 |
| 1995 | 46 020 | 490 230 | 48 578 | 509 424 | -2 558 | -19 194 |
| 1996 | 49 919 | 529 408 | 52 909 | 551 496 | -2 990 | -22 088 |
| 1997 | 55 000 | 590 895 | 57 889 | 612 189 | -2 889 | -21 294 |
| 1998 | 60 544 | 656 466 | 63 307 | 680 233 | -2 763 | -23 767 |
| 1999 | 65 993 | 749 301 | 68 257 | 763 845 | -2 264 | -14 544 |
| 2000 | 73 371 | 854 300 | 80 730 | 956 721 | -7 359 | -102 421 |
| 2001 | 75 586 | 888 392 | 82 887 | 990 341 | -7301 | -101 949 |
| 2002 | 69 578 | 834 375 | 76 942 | 943 244 | -7 364 | -108 869 |
| 2003 | 69 501 | 862 965 | 81 077 | 990 602 | -11 576 | -127 637 |
| 2004 | 70 485 | 866 064 | 77 250 | 969 140 | -6 765 | -103 076 |
| 2005 | 85 407 | 1036 864 | 84 725 | 1 067 718 | 682 | -30 854 |
| 2006 | 90 994 | 1103 265 | 92 608 | 1 148 644 | -1 614 | -45 379 |
| 2007 | 108 595 | 1323 995 | 108 250 | 1 352 507 | 345 | -28 512 |
| 2008 | 113 633 | 1389 232 | 118 278 | 1 471 363 | -4 645 | -82 131 |
| 2009 | 115 222 | 1413 335 | 111 781 | 1 396 319 | 3 441 | 17 016 |
| 2010 | 108 892 | 1344 379 | 113 467 | 1 424 965 | -4 575 | -80 586 |
| 2011 | 120 031 | 1478 115 | 125 175 | 1 552 324 | -5 144 | -74 209 |
| 2012 | 120 889 | 1 512 807 | 125 969 | 1 581 762 | -5 080 | -68 955 |
| 2013 | 116 110 | 1 451 358 | 119 577 | 1 519 612 | -3 467 | -68 254 |
| 2014 | 127 006 | 1 624 731 | 136 042 | 1 726 147 | -9 036 | -101 416 |
| 2015 | 127 958 | 1 591 475 | 127 154 | 1 561 850 | 804 | 29 625 |
| 2016 | 135 554 | 1 644 763 | 135 118 | 1 647 281 | 436 | -2 518 |
| 2017 | 146 220 | 1 804 038 | 149 748 | 1 812 282 | -3 528 | -8 244 |
| 2018 | 150 032 | 1 791 671 | 156 149 | 1 829 058 | -6 117 | 37 387 |

The differences between T1 (national energy balance data) and T2, T3 (plant specific data) results are mainly related to the solid fuels, especially NCVs of Turkish lignite. Because of the own character of the Turkish lignite, its NCV is lower than the lignite in literature. In plant specific data especially NCV of lignite changes in a wide range as 1000-5400 kg/kcal. However, in national balance tables an average NCV value is around 2000 kcal/kg. Based on the quality of lignite used in a specific year, consumption in TJ differs from the national energy balance data. This cause differences in emissions. For example, in 2005, 42% of lignite consumed in 1A1a category has NCVs less than 1500 kcal/kg, 58% has NCVs in 1700-6000 while in national balance table NCV is used as 1400 kcal/kg for 2005. Therefore, lignite consumption in CRF (plant specific data) is 16,2% higher than national balance figures. On the other hand, in 2014, 70% of lignite consumption in plant specific data has NCV less than 2000, while in national balance average NCV for lignite is used as 2100 kcal/kg. That result in 12,1% decrease in lignite consumption in TJ (Table 3.23). With the improvements in the energy balance table in recent years, the difference between the plant specific NCV and national balance average NCV has decreased gradually and it was 1% in 2018.

**Table 3.22 Comparison of solid fuel consumption, 1990-2018**

| | Plant specific data | | | | National energy balance data | | | |
|---|---|---|---|---|---|---|---|---|
| | Hard coal consumption | | Lignite consumption | | Hard coal consumption | | Lignite consumption | |
| Year | (kt) | (TJ) | (kt) | (TJ) | (kt) | (TJ) | (kt) | (TJ) |
| 1990 | 474 | 7 761 | 29 884 | 205 169 | 474 | 7 764 | 29 884 | 202 692 |
| 1991 | 782 | 10 611 | 32 293 | 217 563 | 782 | 10 615 | 32 293 | 219 301 |
| 1992 | 1 339 | 17 428 | 35 318 | 240 051 | 1 339 | 17710 | 35 318 | 241 619 |
| 1993 | 1 298 | 17 027 | 31 917 | 230 652 | 1 298 | 17320 | 31 917 | 232 249 |
| 1994 | 1 441 | 18 977 | 39 701 | 277 193 | 1 441 | 19 222 | 39 701 | 278 917 |
| 1995 | 1 246 | 15 866 | 39 815 | 275 859 | 1 245 | 16 232 | 39 815 | 277 051 |
| 1996 | 1 476 | 18 792 | 42 441 | 302 290 | 1 476 | 19200 | 42 441 | 304 029 |
| 1997 | 1 828 | 22 942 | 45 694 | 324 707 | 1 828 | 23 343 | 45 694 | 326 189 |
| 1998 | 1 884 | 23 778 | 52 115 | 353 093 | 1 885 | 24 332 | 52 115 | 354 785 |
| 1999 | 1 729 | 23 943 | 53 780 | 359 678 | 1 729 | 24 714 | 53780 | 361 615 |
| 2000 | 1 942 | 30 130 | 52 539 | 371 196 | 1 942 | 30100 | 52540 | 373 143 |
| 2001 | 2 167 | 35 209 | 52 883 | 372 593 | 2 179 | 35580 | 52 872 | 374 017 |
| 2002 | 1 945 | 32 979 | 41 883 | 307 731 | 1 945 | 33 005 | 41 901 | 307 004 |
| 2003 | 3 614 | 75 116 | 34 167 | 246 969 | 3 614 | 75 171 | 34 784 | 288 937 |
| 2004 | 4 471 | 99 803 | 32 994 | 242 008 | 4 471 | 99 848 | 32 933 | 242 124 |
| 2005 | 5 174 | 108 533 | 47 414 | 324 826 | 5 171 | 108 531 | 47 413 | 272 791 |
| 2006 | 5 476 | 119 784 | 49 709 | 337 847 | 5 476 | 119 862 | 49 709 | 338 073 |
| 2007 | 5 913 | 131 324 | 60 536 | 408 777 | 5 912 | 131410 | 60 536 | 409 045 |
| 2008 | 6 197 | 137 584 | 65 685 | 441 791 | 6 197 | 137 667 | 65 685 | 442080 |
| 2009 | 6 361 | 140 943 | 62 894 | 424 612 | 6 361 | 141 044 | 62 894 | 397 279 |
| 2010 | 6 935 | 154 215 | 55 437 | 389 958 | 6 934 | 154 272 | 55 436 | 391 552 |
| 2011 | 10 116 | 230 759 | 60 271 | 423 208 | 10 117 | 247 412 | 60 271 | 423 429 |
| 2012 | 11 760 | 287 433 | 54 584 | 378 208 | 11 761 | 287 616 | 54 586 | 378 692 |
| 2013 | 11 707 | 279 108 | 45 919 | 327 977 | 11 707 | 279 238 | 45 919 | 328 369 |
| 2014 | 13 826 | 332 019 | 51 967 | 363 512 | 14 039 | 337 447 | 57 411 | 407 424 |
| 2015 | 16 126 | 389 644 | 48 820 | 350 379 | 16 071 | 388 577 | 48 755 | 349 232 |
| 2016 | 17 966 | 436 847 | 58 974 | 420 041 | 17 966 | 436 657 | 58 974 | 424 445 |
| 2017 | 19 485 | 466 990 | 62 837 | 432 048 | 19 485 | 466 466 | 62 837 | 438 039 |
| 2018 | 23 437 | 555 837 | 71 990 | 482 560 | 23 437 | 555 596 | 71 990 | 487 535 |

### Uncertainties and Time-Series Consistency

AD have been compiled from all public electricity and heat production facilities by Turkish Electricity Transmission Company (TEİAŞ) via survey. As a result of the change made in activity data source there was no bias in total electricity production that was published in Activity Report of TEİAŞ. On the other hand, compared to General Energy Balance Sheets AD of 1.A.1.a category had some bias in amount of fuel used. Uncertainties were determined by experts of MENR. For hard coal and Turkish lignite there is no any bias for AD. Even though there was a 1% bias for bioenergy and wastes in 2017, there is no any bias in 2018.

### $CO_2$ emission factors uncertainties

**Solid fuels:** Turkish lignite other bituminous coal sub-bituminous coal tar coke oven gas blast furnace gas and oxygen steel furnace gas have been used as solid fuels in 1.A.1.a category and combined uncertainty for solid fuels was calculated as 3.5% with Approach 1 method. In this year's submission combined uncertainty estimates of solid fuels are quantified using the Monte Carlo simulation also. Uncertainty in Solid fuels $CO_2$ emissions in 2018 are estimated at -2.97% to +2.91% with Approach 2 method. For more details, please refer to the Uncertainty chapter at the end of the Inventory report in Annex 2.

**Liquid fuels:** Residual fuel oil diesel oil naphtha LPG petroleum coke refinery gas and other oil products have been used as liquid fuels in 1.A.1.a category and combined uncertainty for liquid fuels was calculated as 4.24% with Approach 1 method. In this year's submission combined uncertainty estimates of Liquid fuels are quantified using the Monte Carlo simulation also. Uncertainty in Liquid fuels $CO_2$ emissions in 2018 are estimated at ±2.65% with Approach 2 method. For more details, please refer to the Uncertainty chapter at the end of the Inventory report in Annex 2.

**Gaseous Fuels:** Natural gas has been used as gaseous fuels in 1.A.1.a category and uncertainty for gaseous fuels was calculated as 1.5% with Approach 1 method. In this year's submission combined uncertainty estimates of Gaseous fuels are quantified using the Monte Carlo simulation also. Uncertainty in Gaseous fuels $CO_2$ emissions in 2018 are estimated at -1.46% to +1.47% with Approach 2 method. For more details, please refer to the Uncertainty chapter at the end of the Inventory report in Annex 2.

**Biomass:** Default EF in 2006 IPCC Guidelines on page 1.26 in the landfill gas distribution figure the most frequent EF is 47 000 kg/TJ. Default value that we used for biomass is 54 600 kg/TJ. Bias in between is 13.91% that was taken as uncertainty for biogas. Default EF in 2006 IPCC Guidelines on page 1.27 in the wood/wood waste distribution figure the most frequent EF is 103 000 kg/TJ. Default value that we used for wood/wood waste is 112 000 kg/TJ. Bias in between is 8% that was taken as uncertainty for wood/wood waste. These two biomass fuels' uncertainties were combined using weighted average according to generated heat amount. So the combined uncertainty for biomass is 9.57%.

**Other Fossil Fuels:** Default EFs were taken from 2006 IPCC Guidelines for Industrial wastes (mainly composed of hazardous and clinic waste) and waste oils. On the other hand, there was no default uncertainty value for industrial waste EF throughout the guideline.

EFs uncertainty for $CH_4$ and $N_2O$ was taken from 2006 IPCC Guidelines Vol.2 page 2.38 Table 2.12 and considered as 100% (mid value in the range).

### Recalculation

There is no recalculation for this category.

### Planned Improvement

There is no planned improvement in this category.

## 3.2.4.2. Petroleum refining (Category 1.A.1.b)

### Source Category Description:

All fossil fuels consumed for petroleum refineries process operations were covered in CRF category 1.A.1.b. However autoproducers within the refineries were included in the 1.A.1.a category. The share of GHG emissions as $CO_2$ eq. from petroleum refining in energy industries sector (1A1) was 3.9% in 2018 and it was also 6.1% in 1990.

**Table 3.23 Emissions from petroleum refining, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1A1 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 2 280 | 0.07 | 0.014 | 2 286 | 32 091 | 6.1 |
| 1991 | 2 200 | 0.07 | 0.013 | 2 205 | 31 079 | 5.7 |
| 1992 | 2 316 | 0.07 | 0.013 | 2 321 | 33 474 | 5.4 |
| 1993 | 2 675 | 0.08 | 0.014 | 2 681 | 38 946 | 6.3 |
| 1994 | 2 908 | 0.09 | 0.016 | 2 915 | 42 342 | 5.9 |
| 1995 | 3 009 | 0.09 | 0.016 | 3 017 | 43 872 | 6.0 |
| 1996 | 2 944 | 0.09 | 0.016 | 2 951 | 42 422 | 5.4 |
| 1997 | 3 037 | 0.09 | 0.016 | 3 044 | 44 520 | 5.1 |
| 1998 | 3 108 | 0.10 | 0.017 | 3 115 | 44 866 | 4.8 |
| 1999 | 2 894 | 0.09 | 0.016 | 2 901 | 41 464 | 4.1 |
| 2000 | 2 931 | 0.09 | 0.017 | 2 939 | 41 749 | 3.8 |
| 2001 | 3 030 | 0.09 | 0.017 | 3 037 | 43 607 | 3.8 |
| 2002 | 3 223 | 0.10 | 0.017 | 3 231 | 47 386 | 4.3 |
| 2003 | 3 381 | 0.10 | 0.018 | 3 388 | 49 712 | 4.5 |
| 2004 | 3 567 | 0.11 | 0.019 | 3 575 | 52 654 | 4.7 |
| 2005 | 3 767 | 0.11 | 0.018 | 3 775 | 56 854 | 4.2 |
| 2006 | 3 754 | 0.11 | 0.018 | 3 762 | 57 307 | 3.9 |
| 2007 | 3 719 | 0.11 | 0.018 | 3 727 | 57 130 | 3.3 |
| 2008 | 3 956 | 0.11 | 0.017 | 3 964 | 62 444 | 3.3 |
| 2009 | 2 754 | 0.08 | 0.014 | 2 760 | 41 732 | 2.3 |
| 2010 | 2 706 | 0.07 | 0.010 | 2 710 | 43 348 | 2.4 |
| 2011 | 3 036 | 0.07 | 0.010 | 3 041 | 49 920 | 2.4 |
| 2012 | 3 097 | 0.07 | 0.010 | 3 102 | 50 405 | 2.4 |
| 2013 | 2 702 | 0.06 | 0.009 | 2 706 | 44 678 | 2.2 |
| 2014 | 2 409 | 0.06 | 0.008 | 2 413 | 42 134 | 1.8 |
| 2015 | 4 470 | 0.10 | 0.014 | 4 476 | 79 275 | 3.3 |
| 2016 | 6 372 | 0.13 | 0.018 | 6 381 | 95 149 | 4.4 |
| 2017 | 6 360 | 0.12 | 0.015 | 6 367 | 96 561 | 4.1 |
| 2018 | 6 128 | 0 11 | 0.013 | 6 134 | 95 053 | 3.9 |

Total emissions from petroleum refining were decreased by 233 kt $CO_2$ eq. from 2017 to 2018 (3.8% of decrease).

### Methodological Issues:

Emissions from petroleum refining (CRF 1.A.1.b) were calculated according to 2006 IPCC T2 approach by TurkStat. Fuel consumption, NCVs and carbon content of fuels were compiled directly from refineries by a questionnaire by TurkStat. $CO_2$ emissions from 1.A.1.b were calculated by using average carbon contents of fuels used in the refineries. 2006 IPCC default oxidation rate was used. $CH_4$ and $N_2O$ emissions from CRF category 1.A.1.b, have been estimated by using refineries total fuel consumption and average NCVs for refineries and 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

All refineries are covered in the inventory. AD uncertainty both liquid and gaseous fuels for refineries is considered 2% as indicated in table 2.15 of 2006 IPCC Guidelines Vol.2. Since AD for refineries have been taken directly from the refineries uncertainty level for survey data were considered and to be conservative the maximum uncertainty value was used.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.A.1.b category was performed on the basis of QA/QC plan. It was first confirmed with refinery authorities that AD do not include the autoproducers consumption in the refinery. Calorific values provided by the refinery are checked with national average NCVs of fuels to ensure the use of NCVs in emission estimation. Also carbon content of fuels provided by the refinery checked with IPCC default values to ensure they are in the range.

### Recalculation:

There is no recalculation for this category.

### Planned Improvement:

Emissions from petroleum refining are calculated both plant specific and from national energy balance tables. However, there are some differences in the results. Plant specific results are reported. However, there is a continuous work in order to understand the reasons of the differences.

## 3.2.4.3. Manufacture of solid fuels and other energy industries (Category 1.A.1.c)

### Source Category Description:

All coke production facilities were covered in CRF category 1.A.1.c. The share of GHG emissions as $CO_2$ eq. from manufacture of solid fuels category in 1A1 category was 1.5% in 2018 while it was 5.4% in 1990.

**Table 3.24 Emissions from category 1.A.1.c, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1A1 Category (%) |
|---|---|---|---|---|---|---|
| 1990 | 2 027 | 0.02 | 0.005 | 2 029 | 17 058 | 5.4 |
| 1991 | 2 034 | 0.02 | 0.005 | 2 036 | 17 232 | 5.2 |
| 1992 | 1 815 | 0.02 | 0.005 | 1 817 | 15 004 | 4.2 |
| 1993 | 1 680 | 0.01 | 0.003 | 1 681 | 13 782 | 3.9 |
| 1994 | 1 422 | 0.01 | 0.001 | 1 423 | 11 170 | 2.9 |
| 1995 | 1 429 | 0.01 | 0.001 | 1 429 | 11 623 | 2.8 |
| 1996 | 1 567 | 0.01 | 0.001 | 1 567 | 12 188 | 2.9 |
| 1997 | 1 536 | 0.01 | 0.001 | 1 537 | 11 657 | 2.6 |
| 1998 | 1 504 | 0.01 | 0.001 | 1 505 | 11 550 | 2.3 |
| 1999 | 1 465 | 0.01 | 0.001 | 1 466 | 11 271 | 2.1 |
| 2000 | 1 432 | 0.01 | 0.001 | 1 433 | 10 944 | 1.8 |
| 2001 | 1 399 | 0.01 | 0.001 | 1 399 | 10 483 | 1.7 |
| 2002 | 1 329 | 0.01 | 0.001 | 1 329 | 10 115 | 1.8 |
| 2003 | 1 480 | 0.01 | 0.002 | 1 481 | 11 129 | 2.0 |
| 2004 | 1 477 | 0.02 | 0.004 | 1 478 | 13 403 | 2.0 |
| 2005 | 1 276 | 0.01 | 0.003 | 1 277 | 11 761 | 1.4 |
| 2006 | 1 371 | 0.01 | 0.004 | 1 372 | 12 812 | 1.4 |
| 2007 | 1 247 | 0.01 | 0.002 | 1 248 | 11 737 | 1.1 |
| 2008 | 1 341 | 0.01 | 0.002 | 1 342 | 13 690 | 1.1 |
| 2009 | 1 298 | 0.01 | 0.001 | 1 299 | 11 988 | 1.1 |
| 2010 | 1 721 | 0.01 | 0.001 | 1 722 | 11 494 | 1.5 |
| 2011 | 1 903 | 0.01 | 0.001 | 1 903 | 11 433 | 1.5 |
| 2012 | 1 953 | 0.01 | 0.001 | 1 954 | 12 251 | 1.5 |
| 2013 | 1 956 | 0.01 | 0.001 | 1 956 | 13 916 | 1.6 |
| 2014 | 2 054 | 0.01 | 0.001 | 2 055 | 14 593 | 1.6 |
| 2015 | 2 267 | 0.02 | 0.002 | 2 267 | 15 784 | 1.7 |
| 2016 | 2 028 | 0.01 | 0.001 | 2 028 | 13 402 | 1.4 |
| 2017 | 2 383 | 0.01 | 0.001 | 2 384 | 13 996 | 1.5 |
| 2018 | 2 324 | 0.01 | 0.001 | 2 324 | 13 524 | 1.5 |

Total emissions from manufacture of solid fuels and other energy industries were decreased by 60 kt $CO_2$ eq. from 2017 to 2018 (2.5% of decrease) due to decrease of fuel consumption.

### Methodological Issues:

Emissions from manufacture of solid fuels (CRF 1.A.1.c) were calculated according to 2006 IPCC T3 approach by TurkStat. Coke production in integrated iron and steel production plants have been considered in this category. Coke oven gas, blast furnace gas, and rarely natural gas have been used for heating of coke ovens. Plant specific fuel consumption, NCVs and carbon content of fuels were compiled from each plant. $CO_2$ emissions from 1.A.1.c were calculated by using plant specific AD, carbon contents of fuels and 2006 IPCC default oxidation rates. $CH_4$ and $N_2O$ emissions from CRF category

1.A.1.c, have been estimated by using plant specific fuel consumption and NCVs and 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

All coke production facilities were covered in the inventory. AD uncertainty for solid fuels for coke plants were considered 2% as indicated in Table 2.15 of 2006 IPCC Guidelines Vol.2. Since AD have been taken directly from the coke plants uncertainty level for survey data were considered and to be conservative the maximum uncertainty value was used.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.A.1.c category was performed on the basis of QA/QC plan. Calorific values provided by the coke plants checked with national average NCVs of fuels to ensure the use of NCVs in emission estimation. Also carbon content of fuels provided by the coke plants compared with 2006 IPCC default values. Carbon mass balances on integrated iron and steel plants is done in the IPPU sector as a part of QC/QA of activity data. This control also assures the fuel consumption in the coke ovens.

### Recalculation:

No recalculation in this sector.

### Planned Improvement:

Recently carbon mass balance on integrated iron and steel plants in cooperation with sector experts have been done and good results are taken. There is no planned improvement at the moment.

### 3.2.5. Manufacturing industries and construction (Category 1.A.2)

#### Source Category Description:

This source category consists of manufacturing industries sectors. IPCC categorizes manufacturing industry as iron and steel, nonferrous metal, chemicals, pulp, paper and print, food processing, beverages and tobacco, non-metallic minerals and other industry. Until, 2015 sectoral breakdown of national energy balance tables are not fully in line with CRF categories. In the national energy balance tables, pulp, paper and print sector were presented separately from 2011 onward. It was presented under "other industries (1.A.2.g)" category before 2011. Food processing category included only sugar industry for 1990-2010 periods. From 2011 onward all food processing industries were covered but beverages and tobacco industry were still included under "other industries (1.A.2.g)" category. However, starting from 2015, national energy balance tables are detailed and provided energy consumption for all economical activities so GHG emissions are allocated in line with CRF category.

**Table 3.25 Fuel combustion emissions from manufacturing industry and construction, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in fuel combustion (1A) category (%) |
|---|---|---|---|---|---|---|
| 1990 | 37 004 | 2.17 | 0.347 | 37 162 | 386 908 | 27.5 |
| 1991 | 40 162 | 2.38 | 0.380 | 40 335 | 421 807 | 28.9 |
| 1992 | 39 168 | 2.14 | 0.344 | 39 324 | 422 604 | 26.9 |
| 1993 | 39 832 | 2.10 | 0.340 | 39 986 | 441 625 | 26.2 |
| 1994 | 35 741 | 1.84 | 0.300 | 35 876 | 394 963 | 24.0 |
| 1995 | 39 843 | 2.06 | 0.336 | 39 995 | 452 068 | 24.6 |
| 1996 | 50 376 | 2.88 | 0.462 | 50 586 | 553 552 | 28.1 |
| 1997 | 55 794 | 3.24 | 0.515 | 56 029 | 613 749 | 29.2 |
| 1998 | 55 221 | 3.46 | 0.545 | 55 470 | 597 667 | 29.0 |
| 1999 | 47 158 | 2.87 | 0.456 | 47 365 | 530 985 | 25.2 |
| 2000 | 57 657 | 3.91 | 0.609 | 57 936 | 629 742 | 27.6 |
| 2001 | 45 470 | 2.59 | 0.408 | 45 656 | 504 554 | 23.6 |
| 2002 | 56 856 | 3.58 | 0.560 | 57 112 | 633 369 | 28.5 |
| 2003 | 66 388 | 4.13 | 0.641 | 66 682 | 748 880 | 31.0 |
| 2004 | 63 558 | 4.20 | 0.651 | 63 857 | 750 894 | 28.9 |
| 2005 | 62 731 | 3.85 | 0.595 | 63 004 | 743 394 | 26.4 |
| 2006 | 69 749 | 4.76 | 0.726 | 70 084 | 846 725 | 27.6 |
| 2007 | 71 521 | 5.05 | 0.762 | 71 874 | 867 730 | 25.4 |
| 2008 | 47 169 | 2.63 | 0.401 | 47 354 | 578 884 | 16.9 |
| 2009 | 46 034 | 2.72 | 0.415 | 46 226 | 550 987 | 16.2 |
| 2010 | 52 120 | 3.00 | 0.461 | 52 332 | 639 363 | 18.7 |
| 2011 | 52 380 | 2.91 | 0.443 | 52 585 | 662 028 | 17.5 |
| 2012 | 60 821 | 3.28 | 0.499 | 61 052 | 760 755 | 19.6 |
| 2013 | 52 772 | 2.92 | 0.446 | 52 978 | 648 612 | 17.7 |
| 2014 | 54 233 | 2.93 | 0.444 | 54 438 | 680 149 | 17.2 |
| 2015 | 59 359 | 3.25 | 0.487 | 59 585 | 765 682 | 17.7 |
| 2016 | 59 840 | 3.30 | 0.498 | 60 071 | 785 911 | 17.1 |
| 2017 | 59 958 | 3.18 | 0.478 | 60 180 | 780 500 | 16.1 |
| 2018 | 59 311 | 4.33 | 0.532 | 59 578 | 894 271 | 16.3 |

As can be seen from the table above, there is a sharp decrease in the emissions in 2008. This is due to the global economic downturn in 2008. GHG emissions from 1.A.2 category is 59.6 Mt $CO_2$ eq. in 2018 which is 16.3% of total fuel combustion and 11.4% of total national emissions (excluding LULUCF), whereas GHG emissions from 1.A.2 category was 37.2 Mt $CO_2$ eq. which is 27.5% of total fuel combustion and 15.4% of total national emissions (excluding LULUCF) in 1990. GHG emissions from 1.A.2 category have been decrease by 0.6 Mt $CO_2$ eq. (1%) from 2017 to 2018.

**Table 3.26 GHG emissions from manufacturing industry and construction, 1990-2018**

**(kt $CO_2$ eq.)**

| Year | Total | Iron and steel | Non-ferrous metals | Chemicals | Pulp, paper and print | Food processing beverages and tobacco | Non-metallic minerals | Other industries |
|---|---|---|---|---|---|---|---|---|
| 1990 | 37 162 | 6 686 | 1 088 | 4 893 | NO,IE | 2 909 | 8 262 | 13 324 |
| 1991 | 40 335 | 6 549 | 1 016 | 4 458 | NO,IE | 2 910 | 9 399 | 16 001 |
| 1992 | 39 324 | 7 066 | 1 069 | 4 926 | NO,IE | 2 340 | 8 198 | 15 726 |
| 1993 | 39 986 | 6 406 | 980 | 4 811 | NO,IE | 2 139 | 8 164 | 17 486 |
| 1994 | 35 876 | 6 236 | 1 307 | 4 244 | NO,IE | 1 573 | 9 512 | 13 005 |
| 1995 | 39 995 | 5 591 | 1 756 | 4 962 | NO,IE | 1 685 | 8 794 | 17 207 |
| 1996 | 50 586 | 6 333 | 1 359 | 4 881 | NO,IE | 2 235 | 10 352 | 25 426 |
| 1997 | 56 029 | 6 348 | 1 248 | 4 945 | NO,IE | 2 188 | 9 502 | 31 797 |
| 1998 | 55 470 | 6 152 | 1 167 | 4 086 | NO,IE | 2 641 | 8 395 | 33 030 |
| 1999 | 47 365 | 5 576 | 1 700 | 3 592 | NO,IE | 2 025 | 10 763 | 23 710 |
| 2000 | 57 936 | 6 566 | 1 952 | 3 762 | NO,IE | 2 143 | 9 249 | 34 263 |
| 2001 | 45 656 | 6 732 | 1 989 | 5 074 | NO,IE | 3 979 | 8 846 | 19 035 |
| 2002 | 57 112 | 6 461 | 2 142 | 4 561 | NO,IE | 3 910 | 8 912 | 31 127 |
| 2003 | 66 682 | 6 185 | 1 938 | 4 393 | NO,IE | 2 698 | 10 155 | 41 312 |
| 2004 | 63 857 | 5 057 | 2 188 | 6 857 | NO,IE | 2 341 | 13 219 | 34 194 |
| 2005 | 63 004 | 5 482 | 2 225 | 5 346 | NO,IE | 2 119 | 14 882 | 32 949 |
| 2006 | 70 084 | 4 524 | 2 489 | 4 491 | NO,IE | 2 011 | 14 901 | 41 670 |
| 2007 | 71 874 | 4 640 | 2 400 | 2 058 | NO,IE | 1 384 | 13 495 | 47 896 |
| 2008 | 47 354 | 4 223 | 239 | 945 | NO,IE | 1 371 | 18 594 | 21 983 |
| 2009 | 46 226 | 2 042 | 988 | 2 452 | NO,IE | 459 | 16 514 | 23 770 |
| 2010 | 52 332 | 3 657 | 1 153 | 2 900 | NO,IE | 880 | 21 359 | 22 383 |
| 2011 | 52 585 | 3 990 | 755 | 3 139 | 776 | 3 378 | 25 345 | 15 200 |
| 2012 | 61 052 | 4 380 | 1 173 | 4 646 | 743 | 3 529 | 27 939 | 18 643 |
| 2013 | 52 978 | 4 638 | 760 | 3 942 | 766 | 3 603 | 26 374 | 12 894 |
| 2014 | 54 438 | 4 992 | 989 | 3 705 | 888 | 3 322 | 28 257 | 12 285 |
| 2015 | 59 585 | 5 288 | 1 199 | 6 689 | 963 | 4 359 | 29 955 | 11 133 |
| 2016 | 60 071 | 4 190 | 1 407 | 6 071 | 1 076 | 4 962 | 31 633 | 10 733 |
| 2017 | 60 180 | 4 327 | 1 136 | 5 317 | 942 | 4 921 | 32 578 | 10 959 |
| 2018 | 59 578 | 4 215 | 809 | 7 032 | 982 | 5 092 | 30 183 | 11 266 |

Non-metallic minerals and chemicals and other industries are the main contributors for GHG emissions in 1.A.2 category. The share of non-metallic minerals is 54.1%.

**Table 3.27 Contribution of subsectors of manufacturing industries and construction, 2017-2018**

| | Emissions (kt $CO_2$ eq.) | | Changes from 2017 to 2018 | | Share in manufacturing industry (%) | |
|---|---|---|---|---|---|---|
| | 2017 | 2018 | (kt $CO_2$ eq.) | (%) | 2017 | 2018 |
| **1.A.2 Total** | 60 180 | 59 578 | 110 | 0.2 | 100.0 | 100.0 |
| Iron and steel | 4 327 | 4 215 | 137 | 3.2 | 7.2 | 7.1 |
| Non-ferrous metals | 1 136 | 809 | - 327 | -28.8 | 1.9 | 1.4 |
| Chemicals | 5 317 | 7 032 | - 753 | -12.4 | 8.8 | 11.8 |
| Pulp, paper and print | 942 | 982 | 39 | 4.2 | 1.6 | 1.6 |
| Food processing, beverages and tobacco | 4 921 | 5 092 | 171 | 3.5 | 8.2 | 8.5 |
| Non-metallic minerals | 32 578 | 30 183 | - 2 395 | -7.4 | 54.1 | 50.7 |
| Other industries | 10 959 | 11 266 | 307 | 2.8 | 18.2 | 18.9 |

GHG emissions from 1.A.2 category have been decreased by 1% between 2017 and 2018.

Manufacturing industry and construction category is a key category in terms of emission level and emission trend of $CO_2$ emissions from liquid, solid and gaseous fuels in 2018. It is also a key category in terms of emission level of $CO_2$ from other fossil fuels

### Methodological Issues:

GHG emissions from 1.A.2 sector are calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data are taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used when available, otherwise default $CO_2$ EFs are used. All $CO_2$ EFs are given in table 3.X under 3.2 Fuel Combustion Sector. All $CH_4$ and $N_2O$ EFs are default. The default $CH_4$ and $N_2O$ EFs for 1A2 sector are tabulated below.

**Table 3.28 Defualt $CH_4$ and $N_2O$ EFs for 1A2 sector**

| | Emission Factors | | Source |
|---|---|---|---|
| **Sub Sectors** | **$CH_4$ (kg/TJ)** | **$N_2O$(kg/TJ)** | |
| 1A2 sector | | | |
| Coal products | 10 | 1.5 | Table 2.3 |
| LPG | 1 | 0.1 | Table 2.3 |
| Other Petroluem products | 3 | 0.6 | Table 2.3 |
| Derived gases | 1 | 0.1 | Table 2.3 |
| Wood | 30 | 4 | Table 2.3 |
| Natural gas | 1 | 0.1 | Table 2.3 |

Data on waste incineration for energy recovery have been compiled by TurkStat via survey until 2015 inventory year, after 2015 the waste incineration data were supplied by Directorate of Energy Efficiency and Environment. The list of all waste incineration facilities having waste incineration licenses was determined from the MoEU. Then the amount of waste incinerated and NCVs as MJ/kg by waste types were compiled from all facilities listed by the MoEU. Plant specific waste incineration data and NCVs were used in the GHG estimation. But, 2006 IPCC default EFs were used for $CO_2$, $CH_4$ and $N_2O$ emission estimation.

### Uncertainties and Time-Series Consistency:

The AD for manufacturing industry sector are completely taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were given under subcategories.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$. The same uncertainties were used for all subcategories of 1A2 except 1A2a.

### Source-Specific QA/QC and Verification:

Quality control for 1A2 category was performed on the basis of QA/QC plan. Country specific carbon content of fuels is checked with IPCC default values to ensure that they are in range. Reasonability of IEFs are compared with the previous annual submission and with the 2006 IPCC Guidelines.
The table shows the change in the $CO_2$ IEFs in the time series for liquid and solid fuels.

**Table 3.29 $CO_2$ implied emission factors for 1A2 category**

**(t/TJ)**

| Year | Liquid | Solid | Gaseous |
|---|---|---|---|
| 1990 | 77.8 | 117.7 | 55.5 |
| 1991 | 77.7 | 117.9 | 55.5 |
| 1992 | 78.5 | 119.7 | 55.5 |
| 1993 | 79.4 | 118.8 | 55.5 |
| 1994 | 80.1 | 119.0 | 55.5 |
| 1995 | 79.4 | 117.9 | 55.5 |
| 1996 | 81.1 | 114.0 | 55.5 |
| 1997 | 81.7 | 113.6 | 55.5 |
| 1998 | 80.3 | 112.0 | 55.5 |
| 1999 | 81.3 | 107.1 | 55.5 |
| 2000 | 79.9 | 105.5 | 55.5 |
| 2001 | 79.7 | 112.7 | 55.5 |
| 2002 | 80.7 | 107.4 | 55.5 |
| 2003 | 80.4 | 109.0 | 55.5 |
| 2004 | 80.8 | 100.3 | 55.5 |
| 2005 | 81.8 | 103.5 | 55.5 |
| 2006 | 82.1 | 97.8 | 55.5 |
| 2007 | 84.6 | 97.7 | 55.5 |
| 2008 | 86.4 | 107.0 | 55.5 |
| 2009 | 87.5 | 106.6 | 55.5 |
| 2010 | 85.0 | 106.4 | 55.6 |
| 2011 | 84.7 | 104.2 | 56.6 |
| 2012 | 87.0 | 106.0 | 55.5 |
| 2013 | 88.9 | 105.6 | 55.5 |
| 2014 | 91.2 | 103.9 | 55.5 |
| 2015 | 92.0 | 99.0 | 55.7 |
| 2016 | 93.1 | 92.5 | 55.7 |
| 2017 | 93.2 | 97.7 | 55.6 |
| 2018 | 94.3 | 97.4 | 55.3 |

It can be seen on the table that $CO_2$ IEF for liquid fuels is increasing in the time series. This is because the share of petroleum coke usage has been increased since 1990 while the share of other petroleum products has been decreased since 1990.

On the other hand, it can be seen that $CO_2$ IEF for solid fuels is decreasing in the time series. This is because the share of lignite has been decreased since 1990 while the share of coking coal and coke has been increased since 1990.

### Recalculation:

There is no recalculation in this sector.

**Planned Improvement:**

Prior to 2011 several manufacturing sectors that have their own categories (Pulp, Paper & Print; Non-metallic minerals; Food processing, beverages & tobacco) were not fully separated out in the national energy balance and therefore some or all of the emissions from these categories were reported under section 1A2g. This is because in the calculation of 1A2 subcategories the national energy balance tables are used and national energy balance tables are not created as time series. All relevant institutions are working together in order to overcome this inconsistency problem.

### 3.2.5.1. Iron and steel industries (Category 1.A.2.a)

**Source Category Description:**

The source categories cover emissions from the iron and steel industries including primary and secondary steel producers and rolling mill plants.

Currently there are, 3 integrated facilities producing primary steel and 27 EAF mills producing secondary steel in Turkey. The share of GHG emissions as $CO_2$ eq. from 1A2a in total 1A2 was 7.1% in 2018 while it was 18.0% in 199

**Table 3.30 Fuel combustion emissions from iron and steel industry, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.2 (%) |
|---|---|---|---|---|---|---|
| 1990 | 6 678 | 0.10 | 0.017 | 6 686 | 51 756 | 18.0 |
| 1991 | 6 541 | 0.10 | 0.018 | 6 549 | 52 848 | 16.2 |
| 1992 | 7 057 | 0.11 | 0.019 | 7 066 | 57 620 | 18.0 |
| 1993 | 6 397 | 0.11 | 0.020 | 6 406 | 53 175 | 16.0 |
| 1994 | 6 228 | 0.10 | 0.018 | 6 236 | 50 715 | 17.4 |
| 1995 | 5 584 | 0.10 | 0.017 | 5 591 | 46 104 | 14.0 |
| 1996 | 6 325 | 0.10 | 0.018 | 6 333 | 51 497 | 12.5 |
| 1997 | 6 341 | 0.10 | 0.018 | 6 348 | 50 825 | 11.3 |
| 1998 | 6 145 | 0.10 | 0.017 | 6 152 | 48 952 | 11.1 |
| 1999 | 5 569 | 0.09 | 0.015 | 5 576 | 43 873 | 11.8 |
| 2000 | 6 559 | 0.09 | 0.016 | 6 566 | 49 855 | 11.3 |
| 2001 | 6 726 | 0.09 | 0.015 | 6 732 | 50 208 | 14.7 |
| 2002 | 6 455 | 0.09 | 0.014 | 6 461 | 47 941 | 11.3 |
| 2003 | 6 179 | 0.08 | 0.014 | 6 185 | 46 012 | 9.3 |
| 2004 | 5 052 | 0.07 | 0.011 | 5 057 | 37 403 | 7.9 |
| 2005 | 5 478 | 0.06 | 0.009 | 5 482 | 37 766 | 8.7 |
| 2006 | 4 521 | 0.04 | 0.006 | 4 524 | 30 178 | 6.5 |
| 2007 | 4 637 | 0.04 | 0.006 | 4 640 | 30 080 | 6.5 |
| 2008 | 4 220 | 0.05 | 0.006 | 4 223 | 45 251 | 8.9 |
| 2009 | 2 040 | 0.02 | 0.002 | 2 042 | 19 606 | 4.4 |
| 2010 | 3 652 | 0.08 | 0.012 | 3 657 | 47 148 | 7.0 |
| 2011 | 3 987 | 0.06 | 0.006 | 3 990 | 56 485 | 7.6 |
| 2012 | 4 377 | 0.05 | 0.005 | 4 380 | 50 211 | 7.2 |
| 2013 | 4 635 | 0.06 | 0.006 | 4 638 | 59 556 | 8.8 |
| 2014 | 4 989 | 0.06 | 0.006 | 4 992 | 61 286 | 9.2 |
| 2015 | 5 282 | 0.10 | 0.011 | 5 288 | 71 979 | 8.9 |
| 2016 | 4 186 | 0.07 | 0.008 | 4 190 | 63 997 | 7.0 |
| 2017 | 4 322 | 0.08 | 0.009 | 4 327 | 71 184 | 7.2 |
| 2018 | 4 207 | 0.13 | 0.016 | 4 215 | 70 018 | 7.1 |

Total emissions from iron and steel subcategory was increased by 137 kt $CO_2$ eq. from 2017 to 2018 (3.2% of increase) due to increase of fuel consumption.

### Methodological Issues:

GHG emissions from 1A2a sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EF are used when available, otherwise default $CO_2$ EF are used. All $CH_4$ and $N_2O$ EFs are default.

Integrated iron and steel plants are energy intensive and complex plants. All emission sources were identified together with experts from integrated facilities and emissions are allocated under appropriate CRF categories. Allocation is made in the following way;

- Emissions from electricity generation in auto-producer is considered under Energy-1.A.1.a public electricity and heat production category (based on the reallocation of autoproducers as explained above under source category description of section 3.2.5),
- Emissions from the heating of coke ovens (for coke production) is considered under Energy-1.A.1.c (manufacture of solid fuels) category,
- Emissions from the heating of rolling mills and other miscellaneous combustion emissions are considered under Energy-1.A.2.a iron and steel industry category,
- All carbonaceous fuels (including coke as reducing agent) used in blast furnaces and sinter production are considered under IPPU-2.C.1 iron &steel production.

### Uncertainties and Time-Series Consistency:

Plant specific AD is used for integrated iron and steel production facilities. The AD for EAFs is taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR and TurkStat. AD uncertainties were determined as 10 % for liquid, gaseous, and solid fuels.

EFs uncertainty was determined by sector experts from TurkStat. Uncertainty values were determined as 25% for $CO_2$. EFs uncertainty for $CH_4$ and $N_2O$ was taken from 2006 IPCC Guidelines Vol.2 page 2.38 Table 2.12 and considered as 100% (mid value in the range).

### Source-Specific QA/QC and Verification:

Quality control for 1A2a category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

### Recalculations:

There is no recalculation in this sector.

### Planned Improvement:

There is no planned improvement specific to this category.

### 3.2.5.2. Non-ferrous metal (Category 1.A.2.b)

#### Source Category Description:

The share of GHG emissions as $CO_2$ eq. from 1.A.2.b in total manufacturing industry fuel combustion was 1.4% in 2018 while it was 2.9% in 1990.

**Table 3.31 Fuel combustion emissions from non-ferrous metals, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.2 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 1 084 | 0.05 | 0.009 | 1 088 | 13 187 | 2.9 |
| 1991 | 1 013 | 0.05 | 0.009 | 1 016 | 12 422 | 2.5 |
| 1992 | 1 065 | 0.05 | 0.010 | 1 069 | 12 967 | 2.7 |
| 1993 | 976 | 0.05 | 0.009 | 980 | 11 829 | 2.5 |
| 1994 | 1 302 | 0.06 | 0.012 | 1 307 | 15 676 | 3.6 |
| 1995 | 1 750 | 0.08 | 0.014 | 1 756 | 22 300 | 4.4 |
| 1996 | 1 355 | 0.06 | 0.010 | 1 359 | 18 282 | 2.7 |
| 1997 | 1 244 | 0.06 | 0.011 | 1 248 | 15 854 | 2.2 |
| 1998 | 1 162 | 0.06 | 0.011 | 1 167 | 14 014 | 2.1 |
| 1999 | 1 695 | 0.07 | 0.012 | 1 700 | 23 842 | 3.6 |
| 2000 | 1 945 | 0.10 | 0.016 | 1 952 | 25 668 | 3.4 |
| 2001 | 1 982 | 0.10 | 0.016 | 1 989 | 26 110 | 4.4 |
| 2002 | 2 134 | 0.11 | 0.017 | 2 142 | 28 721 | 3.7 |
| 2003 | 1 932 | 0.08 | 0.013 | 1 938 | 27 655 | 2.9 |
| 2004 | 2 182 | 0.09 | 0.014 | 2 188 | 32 282 | 3.4 |
| 2005 | 2 219 | 0.08 | 0.013 | 2 225 | 33 266 | 3.5 |
| 2006 | 2 482 | 0.09 | 0.014 | 2 489 | 38 255 | 3.6 |
| 2007 | 2 393 | 0.10 | 0.014 | 2 400 | 37 010 | 3.3 |
| 2008 | 239 | 0.00 | 0.000 | 239 | 4 256 | 0.5 |
| 2009 | 987 | 0.02 | 0.002 | 988 | 17 086 | 2.1 |
| 2010 | 1 151 | 0.02 | 0.003 | 1 153 | 20 089 | 2.2 |
| 2011 | 754 | 0.02 | 0.002 | 755 | 13 016 | 1.4 |
| 2012 | 1 171 | 0.03 | 0.003 | 1 173 | 20 393 | 1.9 |
| 2013 | 759 | 0.02 | 0.002 | 760 | 13 379 | 1.4 |
| 2014 | 987 | 0.02 | 0.002 | 989 | 17 371 | 1.8 |
| 2015 | 1 197 | 0.03 | 0.004 | 1 199 | 20 103 | 2.0 |
| 2016 | 1 404 | 0.05 | 0.006 | 1 407 | 22 925 | 2.3 |
| 2017 | 1 134 | 0.04 | 0.005 | 1 136 | 18 034 | 1.9 |
| 2018 | 807 | 0.03 | 0.004 | 809 | 12 650 | 1.4 |

The decrease in total emissions of 1.A.2.b category from 2017 to 2018 is 327 kt $CO_2$ eq. (28.8% of decrease).

### Methodological Issues:

GHG emissions from 1.A.2.b sector were calculated by using 2006 IPCC Tier 1 and Tier 2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used for emission estimation.$CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs. GHG emissions from biomass were estimated by using 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 21.21% for liquid, gaseous and solid fuels.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.A.2.b category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined. $CO_2$, $CH_4$ and $N_2O$ IEFs for all fuels are in the range of 2006 IPCC Guidelines but are changing based on fuel mix used in the sector

### Recalculation:

There is no recalculation in this sector

### Planned Improvement:

There is no planned improvement specific to this category.

## 3.2.5.3. Chemicals (Category 1.A.2.c)

### Source Category Description:

The source category includes manufacture of chemicals, fertilizer, basic pharmaceutical products and rubber and plastic manufacturing. The share of GHG emissions as $CO_2$ eq. from 1.A.2.c in total manufacturing industry was 11.8% in 2018 while it was 13.2% in 1990.

**Table 3.32 Fuel combustion emissions from chemicals, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.2 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 4 875 | 0.24 | 0.040 | 4 893 | 62 789 | 13.2 |
| 1991 | 4 444 | 0.18 | 0.031 | 4 458 | 61 951 | 11.1 |
| 1992 | 4 912 | 0.18 | 0.031 | 4 926 | 70 629 | 12.5 |
| 1993 | 4 799 | 0.17 | 0.028 | 4 811 | 70 578 | 12.0 |
| 1994 | 4 233 | 0.15 | 0.026 | 4 244 | 61 162 | 11.8 |
| 1995 | 4 948 | 0.17 | 0.030 | 4 962 | 71 612 | 12.4 |
| 1996 | 4 868 | 0.17 | 0.029 | 4 881 | 70 777 | 9.6 |
| 1997 | 4 933 | 0.17 | 0.028 | 4 945 | 73 001 | 8.8 |
| 1998 | 4 073 | 0.16 | 0.028 | 4 086 | 56 268 | 7.4 |
| 1999 | 3 581 | 0.14 | 0.025 | 3 592 | 49 495 | 7.6 |
| 2000 | 3 751 | 0.15 | 0.027 | 3 762 | 51 629 | 6.5 |
| 2001 | 5 059 | 0.19 | 0.036 | 5 074 | 69 258 | 11.1 |
| 2002 | 4 549 | 0.16 | 0.028 | 4 561 | 65 875 | 8.0 |
| 2003 | 4 382 | 0.14 | 0.025 | 4 393 | 64 521 | 6.6 |
| 2004 | 6 838 | 0.24 | 0.044 | 6 857 | 97 606 | 10.7 |
| 2005 | 5 334 | 0.16 | 0.026 | 5 346 | 82 163 | 8.5 |
| 2006 | 4 481 | 0.13 | 0.023 | 4 491 | 68 710 | 6.4 |
| 2007 | 2 056 | 0.04 | 0.005 | 2 058 | 36 059 | 2.9 |
| 2008 | 944 | 0.02 | 0.003 | 945 | 16 381 | 2.0 |
| 2009 | 2 445 | 0.10 | 0.014 | 2 452 | 37 259 | 5.3 |
| 2010 | 2 889 | 0.14 | 0.023 | 2 900 | 40 314 | 5.5 |
| 2011 | 3 132 | 0.12 | 0.016 | 3 139 | 49 224 | 6.0 |
| 2012 | 4 635 | 0.16 | 0.023 | 4 646 | 74 005 | 7.6 |
| 2013 | 3 929 | 0.19 | 0.027 | 3 942 | 57 487 | 7.4 |
| 2014 | 3 692 | 0.19 | 0.026 | 3 705 | 54 713 | 6.8 |
| 2015 | 6 672 | 0.26 | 0.034 | 6 689 | 106 985 | 11.2 |
| 2016 | 6 054 | 0.26 | 0.035 | 6 071 | 97 036 | 10.1 |
| 2017 | 5 306 | 0.18 | 0.023 | 5 317 | 87 051 | 8.8 |
| 2018 | 7 010 | 0.33 | 0.044 | 7 032 | 111 968 | 11.8 |

The increase in total emissions of 1.A.2.c category from 2017 to 2018 is 1 714 kt $CO_2$ eq. (32.2% of decrease). The increase in GHG emission of this category is related to the increase in production of main contributing sectors.

### Methodological Issues:

GHG emissions from 1.A.2.c category were calculated using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Data on waste incineration for energy recovery have been compiled by TurkStat via official letter. The amount of waste incinerated and NCVs as MJ/kg by waste types were compiled from the facilities. Plant specific waste incineration data and NCVs were used in the GHG estimation.

Country specific $CO_2$ EFs are used for emission estimation. GHG emissions from waste incineration were estimated by using 2006 IPCC default EFs. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs.

**Uncertainties and Time-Series Consistency:**

The AD was taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 15.81% for liquid, gaseous and solid fuels.

For other fossil fuels it was considered 2% as indicated in table 2.15 of 2006 IPCC Guidelines Vol.2. Since AD for waste incineration have been taken directly from the petrochemical facility, uncertainty level for survey data was considered and to be conservative the maximum uncertainty value was used.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% was taken (mid value in the range) for $CH_4$ and $N_2O$.

**Source-Specific QA/QC and Verification:**

Quality control for 1A2c category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined. Also country specific carbon content of fuels is checked with IPCC default values to ensure they are in the range. Reasonability of IEFs is compared with the previous annual submission and with the 2006 IPCC Guidelines.

**Recalculation:**

There is no recalculation in this sector.

**Planned Improvement:**

There is no planned improvement specific to this category.

### 3.2.5.4. Pulp, paper and print (Category 1.A.2.d)

**Source Category Description:**

The fuel consumption for production of pulp and paper products was separated in the national energy balance tables in 2011. Therefore, emissions from this sector was evaluated under the 1.A.2.g other industries category before 2011. In 2015 national energy balance, print sector is also covered under

1.A.2.d which is included under 1.A.2.g previously. The share of GHG emissions as $CO_2$ eq. from 1.A.2.d in total manufacturing industry fuel combustion was 1.6% in both 2017 and 2018.

**Table 3.33 Fuel combustion emissions from pulp, paper and print, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.2 category (%) |
|---|---|---|---|---|---|---|
| 1990-2010 | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE | NO,IE |
| 2011 | 774 | 0.04 | 0.005 | 776 | 11 127 | 1.5 |
| 2012 | 740 | 0.04 | 0.006 | 743 | 9 972 | 1.2 |
| 2013 | 764 | 0.04 | 0.005 | 766 | 11 118 | 1.4 |
| 2014 | 885 | 0.05 | 0.007 | 888 | 12 315 | 1.6 |
| 2015 | 960 | 0.06 | 0.008 | 963 | 12 946 | 1.6 |
| 2016 | 1 072 | 0.06 | 0.008 | 1 076 | 15 156 | 1.8 |
| 2017 | 939 | 0.05 | 0.007 | 942 | 13 014 | 1.6 |
| 2018 | 977 | 0.07 | 0.010 | 982 | 13 303 | 1.6 |

The increase in total emissions of 1.A.2.d category from 2017 to 2018 is 39.4 kt $CO_2$ eq. (4.2% of increase).

### Methodological Issues:

GHG emissions from 1.A.2.d sector were calculated using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used for emission estimation. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated using 2006 IPCC default EFs. GHG emissions from biomass were estimated using 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 18% for liquid, gaseous and solid fuels.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.A.2.d category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

**Recalculation:**

There is no recalculation in this sector.

**Planned Improvement:**

There is no planned improvement specific to this category.

### 3.2.5.5. Food processing, beverages and tobacco (Category 1.A.2.e)

**Source Category Description:**

The source category includes food processing, manufacturing of beverages, tobacco industry and sugar industry. In the national energy balance tables, the fuel consumption for food processing sector was separated in 2011. For 1990-2010 period only sugar industry, 2011-2014 period all food processing industry were covered under this category but fuel consumption for beverages and tobacco industry cannot be separated and was considered under the section other industries (1.A.2.g). In 2015 national energy balance table, the beverages and tobacco industry are also included under 1.A.2.e category.

The share of GHG emissions as $CO_2$ eq. from 1.A.2.e in total 1.A.2 GHG emissions was 8.5% in 2015 while it was 7.8% in 1990.

**Table 3.34 Fuel combustion emissions from 1A2e category, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.2 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 2 892 | 0.24 | 0.037 | 2 909 | 27 656 | 7.8 |
| 1991 | 2 894 | 0.24 | 0.036 | 2 910 | 27 243 | 7.2 |
| 1992 | 2 327 | 0.19 | 0.029 | 2 340 | 22 194 | 5.9 |
| 1993 | 2 127 | 0.17 | 0.026 | 2 139 | 20 484 | 5.3 |
| 1994 | 1 564 | 0.12 | 0.019 | 1 573 | 15 217 | 4.4 |
| 1995 | 1 676 | 0.13 | 0.020 | 1 685 | 16 894 | 4.2 |
| 1996 | 2 223 | 0.17 | 0.025 | 2 235 | 23 019 | 4.4 |
| 1997 | 2 176 | 0.16 | 0.025 | 2 188 | 22 416 | 3.9 |
| 1998 | 2 626 | 0.21 | 0.032 | 2 641 | 25 636 | 4.8 |
| 1999 | 2 014 | 0.16 | 0.025 | 2 025 | 20 370 | 4.3 |
| 2000 | 2 130 | 0.19 | 0.028 | 2 143 | 20 673 | 3.7 |
| 2001 | 3 960 | 0.26 | 0.042 | 3 979 | 44 605 | 8.7 |
| 2002 | 3 892 | 0.24 | 0.040 | 3 910 | 44 296 | 6.8 |
| 2003 | 2 685 | 0.19 | 0.030 | 2 698 | 29 055 | 4.0 |
| 2004 | 2 330 | 0.16 | 0.025 | 2 341 | 26 249 | 3.7 |
| 2005 | 2 108 | 0.16 | 0.024 | 2 119 | 22 373 | 3.4 |
| 2006 | 2 001 | 0.14 | 0.022 | 2 011 | 22 391 | 2.9 |
| 2007 | 1 377 | 0.10 | 0.015 | 1 384 | 14 436 | 1.9 |
| 2008 | 1 365 | 0.07 | 0.012 | 1 371 | 17 717 | 2.9 |
| 2009 | 456 | 0.04 | 0.006 | 459 | 4 622 | 1.0 |
| 2010 | 877 | 0.05 | 0.007 | 880 | 12 244 | 1.7 |
| 2011 | 3 364 | 0.21 | 0.030 | 3 378 | 43 421 | 6.4 |
| 2012 | 3 515 | 0.21 | 0.030 | 3 529 | 46 695 | 5.8 |
| 2013 | 3 591 | 0.19 | 0.027 | 3 603 | 50 942 | 6.8 |
| 2014 | 3 310 | 0.19 | 0.027 | 3 322 | 46 330 | 6.1 |
| 2015 | 4 342 | 0.26 | 0.037 | 4 359 | 58 490 | 7.3 |
| 2016 | 4 943 | 0.28 | 0.040 | 4 962 | 69 245 | 8.3 |
| 2017 | 4 902 | 0.28 | 0.040 | 4 921 | 67 426 | 8.2 |
| 2018 | 5 047 | 0.99 | 0.068 | 5 092 | 77 611 | 8.5 |

Total GHG emission in 1.A.2.e category increased 171 kt $CO_2$ eq. (3.5% of increase) from 2017 to 2018.

### Methodological Issues:

GHG emissions from 1.A.2.e sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used for emission estimation. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 18% for solid fuels, 5.00% for Liquid fuels and 14.14% for gaseous fuels.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% was taken (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1A2e category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

### Recalculation:

There is no recalculation in this sector.

### Planned Improvement:

There is no planned improvement specific to this category.

## 3.2.5.6. Non-metallic minerals (Category 1.A.2.f)

### Source Category Description:

Glass, cement and ceramic production is covered under this category. For 1990-2010 period only cement industry was covered under this category and fuel consumption for glass and ceramic production were considered under the other industries (1.A.2.g) for that period.

In Turkey, some cement plants have waste incineration license which is given by MoEU. They use waste as alternative fuels and also raw material. Wastes co-incinerated by license are: waste plastics, used tires, waste oils, industrial sludge, tank bottom sludge and sewage sludge, etc. Waste incineration has been carried out since 2004 in cement industry. Waste incineration emissions from cement industry are covered under this category.

1.A.2.f category is energy intensive sector. The share of GHG emissions as $CO_2$ eq. from 1.A.2.f in total manufacturing industry GHG emission was 50.7% in 2018 while it was 22.2% in 1990.

**Table 3.35 Fuel combustion emissions from non-metallic minerals, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.2 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 8 216 | 0.64 | 0.100 | 8 262 | 85 781 | 22.2 |
| 1991 | 9 348 | 0.72 | 0.112 | 9 399 | 97 120 | 23.3 |
| 1992 | 8 155 | 0.60 | 0.093 | 8 198 | 84 425 | 20.8 |
| 1993 | 8 127 | 0.52 | 0.082 | 8 164 | 84 789 | 20.4 |
| 1994 | 9 463 | 0.67 | 0.106 | 9 512 | 95 240 | 26.5 |
| 1995 | 8 750 | 0.61 | 0.097 | 8 794 | 86 732 | 22.0 |
| 1996 | 10 301 | 0.69 | 0.110 | 10 352 | 102 402 | 20.5 |
| 1997 | 9 452 | 0.70 | 0.109 | 9 502 | 93 114 | 17.0 |
| 1998 | 8 354 | 0.57 | 0.091 | 8 395 | 82 232 | 15.1 |
| 1999 | 10 708 | 0.76 | 0.121 | 10 763 | 110 905 | 22.7 |
| 2000 | 9 204 | 0.63 | 0.100 | 9 249 | 94 531 | 16.0 |
| 2001 | 8 804 | 0.58 | 0.093 | 8 846 | 88 560 | 19.4 |
| 2002 | 8 870 | 0.57 | 0.093 | 8 912 | 90 270 | 15.6 |
| 2003 | 10 105 | 0.69 | 0.110 | 10 155 | 100 807 | 15.2 |
| 2004 | 13 152 | 0.92 | 0.147 | 13 219 | 136 689 | 20.7 |
| 2005 | 14 810 | 0.99 | 0.158 | 14 882 | 152 922 | 23.6 |
| 2006 | 14 824 | 1.06 | 0.169 | 14 901 | 156 317 | 21.3 |
| 2007 | 13 419 | 1.07 | 0.167 | 13 495 | 141 561 | 18.8 |
| 2008 | 18 497 | 1.34 | 0.213 | 18 594 | 192 996 | 39.3 |
| 2009 | 16 430 | 1.17 | 0.185 | 16 514 | 165 653 | 35.7 |
| 2010 | 21 240 | 1.66 | 0.258 | 21 359 | 209 775 | 40.8 |
| 2011 | 25 214 | 1.84 | 0.283 | 25 345 | 273 446 | 48.2 |
| 2012 | 27 797 | 2.00 | 0.309 | 27 939 | 298 718 | 45.8 |
| 2013 | 26 240 | 1.88 | 0.292 | 26 374 | 277 274 | 49.8 |
| 2014 | 28 122 | 1.89 | 0.295 | 28 257 | 309 282 | 51.9 |
| 2015 | 29 810 | 2.03 | 0.315 | 29 955 | 332 379 | 50.3 |
| 2016 | 31 482 | 2.09 | 0.330 | 31 633 | 360 842 | 52.7 |
| 2017 | 32 430 | 2.05 | 0.323 | 32 578 | 362 747 | 54.1 |
| 2018 | 30 048 | 2.01 | 0.283 | 30 183 | 351 235 | 50.7 |

The decrease in total GHG emission of 1.A.2.f category is 2 395 kt $CO_2$ eq. (7.4% of increase) from 2017 to 2018.

### Methodological Issues:

GHG emissions from 1.A.2.f sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Data on waste incineration for energy recovery have been compiled by TurkStat via survey until 2015 inventory year, after 2015 the waste incineration data were supplied by General Directorate of Renewable Energy. The amount of waste incinerated and NCVs as MJ/kg by waste types were compiled from the facilities. Plant specific waste incineration data and NCVs were used in the GHG estimation.

Country specific $CO_2$ EFs are used for emission estimation. GHG emissions from waste incineration and biomass were estimated by using 2006 IPCC default EFs. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 25.5% solid fuels, 27.8%for liquid fuels, and 29.2% for gaseous fuels.

For other fossil fuels and biomass, it was considered 2% as indicated in table 2.15 of 2006 IPCC Guidelines Vol.2. Since AD for waste and sewage sludge incineration data have been taken directly from the cement producers uncertainty level for survey data were considered and to be conservative the maximum uncertainty value was used.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.A.2.f category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

$CO_2$, $CH_4$ and $N_2O$ IEFs for all fuels are in the range of 2006 IPCC guidelines but are changing based on fuel mix used in the sector.

The emissions from this sector is compared with the production data of cement, glass and ceramics industry. The emissions and production data is found to be consisting with each in concerning the time series.

### Recalculation:

There was no recalculation in this sector.

### Planned Improvement:

There is no planned improvement specific to this category.

### 3.2.5.7. Other industries (Category 1.A.2.g)

#### Source Category Description:

The manufacturing industry sectors which are not specified above are covered in this category. Based on the improvements in the sectoral breakdown of national energy balance the coverage of this category varies over times. As explained under section 3.2.5.4 and 3.2.5.5 some of the categories are included under 1.A.2.g category until 2011. In 2016 national energy balance tables provide complete sectoral breakdown of all economical activities, the coverage of this category is in line with CRF categorization.

The share of GHG emissions as $CO_2$ eq. from 1.A.2.g in total manufacturing industry fuel combustion was 18.2% in 2017 while it was 35.9% in 1990.

**Table 3.36 Fuel combustion emissions from other industries, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.2 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 13 258 | 0.91 | 0.145 | 13 324 | 145 738 | 35.9 |
| 1991 | 15 922 | 1.10 | 0.175 | 16 001 | 170 223 | 39.7 |
| 1992 | 15 652 | 1.01 | 0.163 | 15 726 | 174 768 | 40.0 |
| 1993 | 17 407 | 1.08 | 0.176 | 17 486 | 200 769 | 43.7 |
| 1994 | 12 951 | 0.72 | 0.119 | 13 005 | 156 954 | 36.2 |
| 1995 | 17 135 | 0.97 | 0.158 | 17 207 | 208 427 | 43.0 |
| 1996 | 25 304 | 1.70 | 0.268 | 25 426 | 287 576 | 50.3 |
| 1997 | 31 649 | 2.05 | 0.324 | 31 797 | 358 538 | 56.8 |
| 1998 | 32 862 | 2.36 | 0.365 | 33 030 | 370 563 | 59.5 |
| 1999 | 23 591 | 1.65 | 0.259 | 23 710 | 282 500 | 50.1 |
| 2000 | 34 068 | 2.75 | 0.422 | 34 263 | 387 385 | 59.1 |
| 2001 | 18 940 | 1.37 | 0.206 | 19 035 | 225 814 | 41.7 |
| 2002 | 30 957 | 2.41 | 0.367 | 31 127 | 356 265 | 54.5 |
| 2003 | 41 104 | 2.95 | 0.450 | 41 312 | 480 830 | 62.0 |
| 2004 | 34 004 | 2.73 | 0.410 | 34 194 | 420 665 | 53.5 |
| 2005 | 32 781 | 2.40 | 0.364 | 32 949 | 414 903 | 52.3 |
| 2006 | 41 441 | 3.29 | 0.493 | 41 670 | 530 874 | 59.5 |
| 2007 | 47 639 | 3.69 | 0.555 | 47 896 | 608 583 | 66.6 |
| 2008 | 21 905 | 1.14 | 0.166 | 21 983 | 302 283 | 46.4 |
| 2009 | 23 674 | 1.38 | 0.207 | 23 770 | 306 760 | 51.4 |
| 2010 | 22 310 | 1.05 | 0.158 | 22 383 | 309 794 | 42.8 |
| 2011 | 15 154 | 0.64 | 0.101 | 15 200 | 215 309 | 28.9 |
| 2012 | 18 587 | 0.79 | 0.123 | 18 643 | 260 761 | 30.5 |
| 2013 | 12 854 | 0.54 | 0.087 | 12 894 | 178 856 | 24.3 |
| 2014 | 12 248 | 0.53 | 0.080 | 12 285 | 178 853 | 22.6 |
| 2015 | 11 097 | 0.52 | 0.076 | 11 133 | 162 800 | 18.7 |
| 2016 | 10 699 | 0.50 | 0.072 | 10 733 | 156 710 | 17.9 |
| 2017 | 10 925 | 0.50 | 0.070 | 10 959 | 161 044 | 18.2 |
| 2018 | 11 215 | 0.77 | 0.106 | 11 266 | 177 276 | 18.9 |

Total GHG emission in 1.A.2.g category increased 307 kt $CO_2$ eq. (2.9% of increase) from 2017 to 2018.

### Methodological Issues:

GHG emissions from 1.A.2.g sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used for emission estimation. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 70.71% for liquid, gaseous and solid fuels.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.A.2.g category was performed on the basis of QA/QC plan.$CO_2$, $CH_4$ and $N_2O$ IEFs for all fuels are in the range of 2006 IPCC Guidelines.

### Recalculation:

There is no recalculation in this sector.

### Planned Improvement:

There is no planned improvement specific to this category.

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

Estimation of emissions in Transport sector are carried out in the sub-categories listed below:

- Domestic Aviation (1.A.3.a)
- Road Transportation (1.A.3.b)
- Railways (1.A.3.c)
- Domestic water-borne Navigation (1.A.3.d)
- Pipeline (other transportation) (1.A.3.e.i)

Emissions from this category were 213.3% higher in 2018 than in 1990, and on average emissions increased by more than 7.4% annually.

In 2018, transport sector contributed to 84.5 Mt $CO_2$ eq. emissions (Figure 3.13). GHG emissions (in $CO_2$ eq.) from transport sector as a share of total fuel combustion was 23.1% in 2018 while it was 20% in 1990.

GHG emissions by transport mode are given in Table 3.38. As shown in Figure 3.14, road transportation is the major $CO_2$ source contributing to 93.4% of transport emissions in 2018. Contribution of domestic aviation is 4.4%, domestic water-borne navigation is 1.1%, and railways are 0.5% in 2018. The share of pipeline transportation is 0.6%.

**Figure 3.13 GHG emissions for transportation sector, 1990-2018**

**Table 3.37 GHG emissions from transport sector, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | TJ |
|---|---|---|---|---|---|
| 1990 | 26 251 | 4.0 | 2.1 | 26 969 | 364 617 |
| 1991 | 24 982 | 3.8 | 2.0 | 25 673 | 347 164 |
| 1992 | 25 640 | 4.2 | 2.1 | 26 366 | 356 995 |
| 1993 | 31 269 | 5.0 | 2.5 | 32 143 | 435 401 |
| 1994 | 29 789 | 4.9 | 2.4 | 30 640 | 415 493 |
| 1995 | 33 180 | 5.5 | 2.7 | 34 113 | 463 044 |
| 1996 | 35 277 | 5.9 | 2.8 | 36 271 | 492 752 |
| 1997 | 33 702 | 7.0 | 2.7 | 34 690 | 474 602 |
| 1998 | 31 817 | 7.5 | 2.6 | 32 782 | 450 289 |
| 1999 | 33 635 | 7.8 | 2.6 | 34 617 | 475 418 |
| 2000 | 35 490 | 8.9 | 2.5 | 36 465 | 503 352 |
| 2001 | 35 534 | 8.4 | 2.4 | 36 455 | 503 006 |
| 2002 | 35 316 | 7.9 | 2.4 | 36 234 | 498 404 |
| 2003 | 36 893 | 8.1 | 2.4 | 37 825 | 520 124 |
| 2004 | 41 061 | 8.3 | 2.6 | 42 048 | 578 405 |
| 2005 | 41 044 | 8.6 | 2.6 | 42 041 | 578 712 |
| 2006 | 44 377 | 9.2 | 2.7 | 45 424 | 625 285 |
| 2007 | 50 989 | 10.4 | 2.8 | 52 099 | 718 824 |
| 2008 | 47 117 | 10.5 | 2.6 | 48 166 | 668 762 |
| 2009 | 46 871 | 11.0 | 2.6 | 47 907 | 664 439 |
| 2010 | 44 383 | 11.4 | 2.4 | 45 392 | 630 304 |
| 2011 | 46 367 | 11.5 | 2.5 | 47 386 | 657 982 |
| 2012 | 61 249 | 12.6 | 3.2 | 62 525 | 862 220 |
| 2013 | 67 478 | 13.0 | 3.6 | 68 865 | 948 734 |
| 2014 | 72 084 | 13.6 | 3.8 | 73 559 | 1 013 762 |
| 2015 | 74 263 | 14.5 | 3.9 | 75 789 | 1 047 749 |
| 2016 | 80 208 | 15.4 | 4.2 | 81 841 | 1 129 546 |
| 2017 | 82 954 | 15.4 | 4.4 | 84 659 | 1 180 256 |
| 2018 | 82 788 | 15.9 | 4.4 | 84 502 | 1 180 609 |

**Table 3.38 GHG emissions by transport mode, 1990-2018**

**(kt $CO_2$ eq.)**

| Year | Total | Domestic aviation | Road transportation | Railways | Domestic navigation | Other transportation |
|---|---|---|---|---|---|---|
| 1990 | 26 969 | 923 | 24 777 | 721 | 509 | 39 |
| 1991 | 25 673 | 1 053 | 23 288 | 740 | 543 | 49 |
| 1992 | 26 366 | 1 118 | 23 871 | 685 | 638 | 54 |
| 1993 | 32 143 | 1 489 | 29 178 | 751 | 664 | 60 |
| 1994 | 30 640 | 1 764 | 27 419 | 768 | 623 | 65 |
| 1995 | 34 113 | 2 775 | 29 760 | 768 | 726 | 83 |
| 1996 | 36 271 | 3 048 | 31 628 | 799 | 699 | 97 |
| 1997 | 34 690 | 3 215 | 29 858 | 799 | 698 | 120 |
| 1998 | 32 782 | 3 311 | 27 881 | 740 | 726 | 124 |
| 1999 | 34 617 | 2 868 | 30 219 | 722 | 658 | 150 |
| 2000 | 36 465 | 3 099 | 31 850 | 713 | 623 | 180 |
| 2001 | 36 455 | 3 358 | 31 512 | 587 | 800 | 198 |
| 2002 | 36 234 | 2 503 | 32 084 | 612 | 822 | 213 |
| 2003 | 37 825 | 2 713 | 33 347 | 629 | 891 | 245 |
| 2004 | 42 048 | 4 859 | 35 090 | 629 | 1 228 | 242 |
| 2005 | 42 041 | 4 089 | 35 532 | 757 | 1 299 | 364 |
| 2006 | 45 424 | 4 512 | 38 370 | 761 | 1 464 | 317 |
| 2007 | 52 099 | 6 019 | 43 674 | 470 | 1 598 | 338 |
| 2008 | 48 166 | 5 218 | 40 559 | 499 | 1 543 | 348 |
| 2009 | 47 907 | 5 149 | 40 204 | 484 | 1 632 | 437 |
| 2010 | 45 392 | 2 862 | 39 941 | 517 | 1 682 | 390 |
| 2011 | 47 386 | 3 344 | 40 899 | 532 | 2 242 | 370 |
| 2012 | 62 525 | 3 727 | 56 310 | 492 | 1 614 | 381 |
| 2013 | 68 865 | 3 754 | 62 889 | 505 | 1 154 | 563 |
| 2014 | 73 559 | 4 090 | 66 967 | 562 | 1 348 | 593 |
| 2015 | 75 789 | 4 205 | 69 309 | 480 | 1 147 | 647 |
| 2016 | 81 841 | 4 281 | 75 595 | 374 | 970 | 621 |
| 2017 | 84 659 | 3 838 | 78 706 | 413 | 944 | 758 |
| 2018 | 84 502 | 3 688 | 78 907 | 435 | 931 | 542 |

**Figure 3.14 GHG emission trend by transport mode, 1990-2018**

Throughout the time series, road transportation was the dominant source of emissions in the category, responsible for between 83% (2004) and 92% (1990). The second largest source was domestic aviation, ranging from 3% (1990) and 12% (2007). Between 2004 and 2009, when the share of emissions from road transportation was at their lowest, the share from domestic aviation was the highest. When analyzed in detail (Figure 3.15), there are different factors influencing GHG emissions resulting from domestic aviation. Fuel consumption rose steadily in domestic aviation sector up to year 1999. As a consequence of economic reasons, fuel consumption values declined from 1999 to 2002. However, the rearrangement policy of MoTI resulted in a sudden improvement in civil aviation sector. Then again, the number of flights and fuel consumption started to increase. However, while the number of flights annually increased, fuel consumption and GHG emissions showed inter-annual variation following parallel trends. Especially, from 2007 to 2010 fuel consumption and GHG emissions declined by approximately 50% while the number of flights increased by roughly 35%. This decoupling could partially be explained with renewal of the Turkish air fleet and the global economic crisis but the main reason of decoupling could be determined with improving data quality in domestic aviation sector.

**Figure 3.15 Comparison of number of flights, fuel consumption and GHG emissions of civil aviation, 1990-2018**

The other transportation mode needed to be analyzed is road transportation (Figure 3.16). In road transportation until the year 1997, only diesel oil and gasoline were used. Utilization of LPG started in 1997 and consumption increased steadily. Then, diesel oil consumption and LPG consumption increased while gasoline consumption declined. From 2007 to 2010, diesel oil consumption decreased probably because of the global economic crisis. After that, there is remarkable rise in diesel fuel oil consumption. When analyzed in detail, it is determined that data of diesel fuel used in agriculture sector have not been separated from those used in road transportation since 2011. That is why there was a large increase in GHG emissions resulting from diesel fuel between 2011 (27.035 kt. $CO_2$ eq.) and 2018 (61.592 kt. $CO_2$ eq.), an increase of 128%.

**Figure 3.16 Emission distributions by fuel types in road transportation, 1990-2018**

**Figure 3.17 Passenger-km by road, 1998-2018 (1)**

(1) https://data.oecd.org/transport/passenger-transport.htm

As seen from the figure 3.17, million passenger kilometers has been on an increasing trend over the years. Especially, from 2008 onward the increase has been significant year by year. The reasoning behind this is the number of cars has increased which leads to increase in the number of people traveling by road.

**Figure 3.18 Passenger-km by railway, 1998-2018 (2)**

(2) https://data.oecd.org/transport/passenger-transport.htm

Above figure represents million passenger kilometers by rail. In recent years, Turkey has put a lot of emphasis on redeveloping and modernizing the rail infrastructure which has had an effect on the number of passenger kilometers over the years. The modernization of the rail infrastructure requires a temporary stoppage of railway transport and once the modernization is complete restarting the operation. That is why there happened a fluctuation in emissions from 2011 to 2018.

### Source Category Description:

The source category comprises GHG emissions resulting from transport sector as follows; aviation, railways, road transportation, navigation and pipeline transport (other transportation). In addition to these, international aviation and international navigation were also included in this category. Among these categories;

- Domestic aviation in terms of $CO_2$ emissions from jet fuel (level and trend),
- Road transportation in terms of $CO_2$ emissions from diesel fuel, LPG, gasoline and other ones (biofuel and natural gas) (level and trend),
- Domestic navigation in terms of $CO_2$ emissions from diesel fuel and fuel oil,

Emissions from civil aviation were covered as international aviation and domestic aviation under (1.A.3.a.i) and (1.A.3.a.ii) categories.

Road transportation is the largest contributor to transport emissions and estimations were made under a wide variety of vehicle types using not only gasoline but also diesel fuel and LPG. It is covered under category (1.A.3.b).

Emissions from railways were reported under category (1.A.3.c).

Emission estimates from the navigation section cover international water-borne navigation (1.A.3.d.i) and domestic navigation-coastal shipping (1.A.3.d.ii).

Pipeline transportation emissions are reported under the category other transportation (1.A.3.e.i).

### Methodological Issues:

Turkey implements Tier 1 and Tier 2 methodologies to estimate GHG emissions of mobile sources for the time series 1990-2017, as shown in equation below. The general method is presented here, and any specific circumstances in the implementation of the method is described separately for each category.

$$Emissions = \sum_{a} [Fuel_a * EF_a]$$

Where:
Emission = Emissions of $CO_2$ (kg)
$Fuel_a$ = fuel sold (TJ)
$EF_a$ = emission factor (kg/TJ). This is equal to the carbon content of the fuel multiplied by 44/12.
a = type of fuel (e.g. petrol, diesel, natural gas, LPG etc.)

All EFs were taken from the 2006 IPCC Guidelines.

The IPCC methods used in transport sector calculations are listed in Table 3.39.

**Table 3.39 Method used in the calculation of GHG emissions by transport modes**

| Modes of transport | $CO_2$ | $CH_4$ | $N_2O$ | Tier I | Tier II |
|---|---|---|---|---|---|
| Domestic aviation | √ | √ | √ | X | X |
| Road transportation | √ | √ | √ | X | X |
| Railways | √ | √ | √ | X | X |
| Domestic navigation | √ | √ | √ | X | X |
| Pipeline transportation | √ | √ | √ | X | X |

For the Transport source category (1.A.3), the following data sources were used to estimate and calculate emissions:

- Fuel consumption values for source categories (1.A.3.a.i), (1.A.3.a.ii), (1.A.3.b), (1.A.3.c), (1.A.3.d.i), (1.A.3.d.ii) and (1.A.3.e.i) were provided by MENR in the form of the national energy balance tables, MAPEG and Petroleum Pipeline Corporation.
- Air traffic data is provided by Directorate of General (DG) of State Airports Authority for National Aviation (1.A.3.a.ii). Emissions were estimated by using IPCC T2 methodology explained in IPCC Guidelines for National GHG Inventories (IPCC, 2006). The calculation methodology is based on the national energy consumption data and air traffic data for each airport in terms of aircraft type. For the activities, default EFs were used. Air traffic data which consists of landing and take-off (LTO) cycles and cruise is processed for all 55 airports in Turkey. All activities below 914 m were included in LTO cycle; movements over 914 m altitude were covered in the cruise phase. Domestic flights for all aircraft types have been accounted considering estimated individual fuel consumption values. The necessary EFs for LTO and cruise for each type of aircraft have been chosen from IPCC reference manual.
- The emissions from road transportation were calculated by using IPCC Tier 1&2 methodology. Other values for database improvement were provided from DG of Highways, DG of Turkish State Railways and DG of Civil Aviation.

### Source-Specific QA/QC and Verification:

The IPCC Good Practice Guidance is used for the QA/QC procedures of National GHG Emission Inventory. For the quality control purposes, GHG emissions, estimated by using T2 approach, were compared with emissions estimated by using T1 approach. If the difference between the emission values obtained by both methods is less than 5%, calculations were considered to be appropriate.

### Recalculation:

There is no recalculation for this category.

### 3.2.6.1. Civil aviation (Category 1.A.3.a)

The domestic aviation source category was a key category in 2018, in terms of both the level and trend analysis of $CO_2$ emissions from the jet fuel. In domestic aviation only jet fuel is consumed.

Figure 3.19 and Figure 3.20 illustrate the total emissions and the emissions of $N_2O$ and $CH_4$ increasing trends as $CO_2$ eq. $CO_2$ eq. emissions have increased approximately 368% since 1990 and reached to 3.69 Mt $CO_2$ in 2018. The calculated amounts of $N_2O$ and $CH_4$ emissions were 37.78 kt. $CO_2$ eq. and 1.66 kt. $CO_2$ eq. respectively in 2018. There was a relatively large decrease in $CO_2$ emissions observed between 2009 and 2010 (a 44% decline) owing to the global economic crisis. In spite of this emissions in recent years have increased.

**Figure 3.19 GHG emissions for domestic aviation, 1990-2018**

**Figure 3.20 $CH_4$ and $N_2O$ emissions for domestic aviation, 1990-2018**

### Methodological issues:

Emissions were estimated by using the IPCC T2 methodology explained in the 2006 IPCC Guidelines. In the Tier 2 method, it is necessary to divide the operations of aircraft into landing and take-off (LTO) and cruise phases, as implemented through equations below. The calculation methodology is based on the national energy consumption data and air traffic data for each airport in terms of aircraft type.

$$Total\ emissions = LTOemissions + cruiseemissions$$

$$LTOemissions = NumberofLTOs * EF_{LTO}$$

$$LTOfuelconsumption = NumberofLTOs * FuelconsumptionperLTO$$

$$Cruiseemissions = (TotalFuelConsumption - LTOFuelConsumption) * EF_{Cruise}$$

### Collection of activity data:

Air traffic data which consists of LTO cycles and cruise is provided by Directorate of General of State Airports Authority for all civil airports in Turkey. The number of LTO values for all aircraft types were provided for each airport. All activities below 914 m were included as LTO cycles; movements over 914 m altitude were covered in the cruise phase. Domestic flights for all aircraft types have been accounted considering estimated individual fuel consumption values in the year 2018 total number of LTO's in domestic travel for all aircraft types is 892 405. Passenger and freight traffic from 2006 to 2017 is also

given in Figure 3.21 and Figure 3.22 respectively. Figure 3.23 shows the number of domestic LTOs for Turkish airports from 1990 to 2018.

**Figure 3.21 Passenger traffic, 2006-2018**

**Figure 3.22 Freight traffic, 2006-2018**

EFs for all aircraft types were obtained from 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines). Default values were applied for aircrafts where specific data is not available. In the light of these explanations, the total fuel consumption for domestic aviation is 1.171 Mt. To calculate the LTO fuel consumption, Turkey multiplied the number of LTOs by the relevant LTO fuel consumption

factors. The calculated total LTO fuel consumption is 0.692 Mt. To estimate cruise fuel consumption, Turkey subtracts LTO fuel consumption from total fuel consumption for each year of the time series. In 2018, cruise fuel consumption is 0.479 Mt.

**Figure 3.23 Number of domestic LTO, 1990-2018**

### Choice of Emission Factor:

LTO fuel consumption factors, as well as default $CO_2$, $CH_4$ and $N_2O$ emission factors for all aircraft types were obtained from the 2006 IPCC Guidelines (Table 3.6.9). Default emission factor values were applied for aircrafts where specific data are not available. The resulting $CO_2$ emission values of 2.140 Mt and 1.509 Mt were reported for LTO and cruise respectively. $CO_2$, $CH_4$ and $N_2O$ emission values are given in Table 3.40.

**Table 3.40 GHG emissions from domestic aviation, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | TJ |
|---|---|---|---|---|---|
| 1990 | 914 | 0.01 | 0.03 | 923 | 13 030 |
| 1991 | 1 043 | 0.01 | 0.03 | 1 053 | 14 755 |
| 1992 | 1 107 | 0.02 | 0.04 | 1 118 | 15 648 |
| 1993 | 1 474 | 0.02 | 0.05 | 1 489 | 20 875 |
| 1994 | 1 747 | 0.02 | 0.06 | 1 764 | 24 653 |
| 1995 | 2 748 | 0.04 | 0.09 | 2 775 | 38 670 |
| 1996 | 3 018 | 0.04 | 0.10 | 3 048 | 42 642 |
| 1997 | 3 183 | 0.04 | 0.10 | 3 215 | 45 028 |
| 1998 | 3 278 | 0.04 | 0.11 | 3 311 | 46 302 |
| 1999 | 2 840 | 0.04 | 0.09 | 2 868 | 40 106 |
| 2000 | 3 068 | 0.04 | 0.10 | 3 099 | 43 296 |
| 2001 | 3 325 | 0.03 | 0.11 | 3 358 | 47 044 |
| 2002 | 2 478 | 0.03 | 0.08 | 2 503 | 35 266 |
| 2003 | 2 686 | 0.03 | 0.09 | 2 713 | 37 923 |
| 2004 | 4 811 | 0.04 | 0.16 | 4 859 | 68 082 |
| 2005 | 4 048 | 0.05 | 0.13 | 4 089 | 57 276 |
| 2006 | 4 467 | 0.05 | 0.15 | 4 512 | 63 194 |
| 2007 | 5 960 | 0.05 | 0.19 | 6 019 | 84 334 |
| 2008 | 5 166 | 0.06 | 0.17 | 5 218 | 73 201 |
| 2009 | 5 096 | 0.07 | 0.17 | 5 149 | 72 049 |
| 2010 | 2 833 | 0.04 | 0.09 | 2 862 | 40 043 |
| 2011 | 3 308 | 0.04 | 0.12 | 3 344 | 47 199 |
| 2012 | 3 688 | 0.05 | 0.13 | 3 727 | 52 686 |
| 2013 | 3 715 | 0.05 | 0.13 | 3 754 | 52 467 |
| 2014 | 4 047 | 0.05 | 0.14 | 4 090 | 57 243 |
| 2015 | 4 162 | 0.06 | 0.14 | 4 205 | 58 824 |
| 2016 | 4 237 | 0.06 | 0.14 | 4 281 | 59 884 |
| 2017 | 3 798 | 0.06 | 0.13 | 3 838 | 53 259 |
| 2018 | 3 648 | 0.07 | 0.13 | 3 688 | 52 217 |
| **Changes from 1990 (%)** | 299.1 | 600 | 333.3 | 299.6 | 300.7 |

**Table 3.41 GHG emissions for LTO and cruise in domestic aviation, 2018 (kt)**

| | $CO_2$ | $CH_4$ | $N_2O$ | Jet kerosene |
|---|---|---|---|---|
| Total | 3 648 | 0.07 | 0.127 | 1 171 |
| LTO | 2 140 | 0.07 | 0.081 | 692.2 |
| Cruise | 1 509 | - | 0.046 | 478.9 |

**Table 3.42 IEFs of domestic aviation 1990-2018**

| | | IEFs | | |
|---|---|---|---|---|
| | Activity | $CO_2$ | $CH_4$ | $N_2O$ |
| Year | TJ | t/TJ | kg/TJ | kg/TJ |
| 1990 | 13 030 | 70.13 | 0.96 | 2.29 |
| 1991 | 14 755 | 70.67 | 0.96 | 2.28 |
| 1992 | 15 648 | 70.72 | 0.98 | 2.42 |
| 1993 | 20 875 | 70.60 | 0.99 | 2.41 |
| 1994 | 24 653 | 70.84 | 0.98 | 2.29 |
| 1995 | 38 670 | 71.06 | 0.95 | 2.29 |
| 1996 | 42 642 | 70.77 | 0.99 | 2.28 |
| 1997 | 45 028 | 70.69 | 0.98 | 2.30 |
| 1998 | 46 302 | 70.79 | 0.84 | 2.31 |
| 1999 | 40 106 | 70.80 | 0.94 | 2.31 |
| 2000 | 43 296 | 70.86 | 0.86 | 2.31 |
| 2001 | 47 044 | 70.69 | 0.70 | 2.30 |
| 2002 | 35 266 | 70.28 | 0.96 | 2.26 |
| 2003 | 37 923 | 70.82 | 0.88 | 2.30 |
| 2004 | 68 082 | 70.67 | 0.57 | 2.28 |
| 2005 | 57 276 | 70.68 | 0.80 | 2.31 |
| 2006 | 63 194 | 70.68 | 0.84 | 2.32 |
| 2007 | 84 334 | 70.68 | 0.57 | 2.30 |
| 2008 | 73 201 | 70.57 | 0.76 | 2.31 |
| 2009 | 72 049 | 70.74 | 0.97 | 2.38 |
| 2010 | 40 043 | 70.75 | 0.95 | 2.36 |
| 2011 | 47 199 | 70.09 | 0.92 | 2.46 |
| 2012 | 52 686 | 69.99 | 0.88 | 2.45 |
| 2013 | 52 467 | 70.81 | 0.92 | 2.45 |
| 2014 | 57 243 | 70.70 | 0.90 | 2.44 |
| 2015 | 58 824 | 70.75 | 0.98 | 2.39 |
| 2016 | 59 884 | 70.75 | 0.99 | 2.39 |
| 2017 | 53 259 | 71.32 | 1.12 | 2.43 |
| 2018 | 52 217 | 69.86 | 1.27 | 2.43 |

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 5.48% liquid fuels.

EF uncertainty for $CO_2$ was considered as 5% as indicated in 2006 IPCC Guidelines Vol. 2 page 3.69. For $CH_4$ and $N_2O$ mid value of default uncertainty given in 2006 IPCC Guidelines as 80% and 85% were considered respectively.

### Recalculation:

There is no recalculation for this category.

### Planned Improvement:

Work on data quality regarding fuel consumption and air traffic will be continued in co-operation with experts from related institutions.

## 3.2.6.2. Road transportation (Category 1.A.3.b)

Road Transportation source category was a key category, in terms of emission level of $CO_2$ from diesel oil, LPG and gasoline in 2018. This category was also a key category in terms of emission trend of $CO_2$ from gasoline and diesel oil. The results according to IPCC Tier 1&2 were in Table 3.43.

**Table 3.43 GHG emissions from road transportation, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | TJ |
|---|---|---|---|---|---|
| 1990 | 24 143 | 3.9 | 1.804 | 24 777 | 335 589 |
| 1991 | 22 686 | 3.7 | 1.712 | 23 288 | 315 543 |
| 1992 | 23 232 | 4.0 | 1.804 | 23 871 | 323 808 |
| 1993 | 28 403 | 4.9 | 2.192 | 29 178 | 395 708 |
| 1994 | 26 672 | 4.8 | 2.105 | 27 419 | 372 206 |
| 1995 | 28 942 | 5.3 | 2.301 | 29 760 | 404 093 |
| 1996 | 30 753 | 5.7 | 2.458 | 31 628 | 429 564 |
| 1997 | 28 993 | 6.9 | 2.329 | 29 858 | 408 624 |
| 1998 | 27 033 | 7.3 | 2.233 | 27 881 | 383 300 |
| 1999 | 29 346 | 7.6 | 2.287 | 30 219 | 415 241 |
| 2000 | 30 988 | 8.8 | 2.158 | 31 850 | 439 986 |
| 2001 | 30 694 | 8.3 | 2.050 | 31 512 | 434 724 |
| 2002 | 31 264 | 7.7 | 2.106 | 32 084 | 441 038 |
| 2003 | 32 517 | 7.9 | 2.119 | 33 347 | 458 427 |
| 2004 | 34 230 | 8.2 | 2.203 | 35 090 | 482 069 |
| 2005 | 34 668 | 8.4 | 2.195 | 35 532 | 488 494 |
| 2006 | 37 463 | 9.0 | 2.289 | 38 370 | 527 725 |
| 2007 | 42 689 | 10.2 | 2.447 | 43 674 | 601 495 |
| 2008 | 39 630 | 10.3 | 2.253 | 40 559 | 562 707 |
| 2009 | 39 289 | 10.7 | 2.170 | 40 204 | 556 696 |
| 2010 | 39 033 | 11.2 | 2.106 | 39 941 | 554 362 |
| 2011 | 39 995 | 11.2 | 2.093 | 40 899 | 567 688 |
| 2012 | 55 142 | 12.4 | 2.882 | 56 310 | 775 067 |
| 2013 | 61 607 | 12.8 | 3.224 | 62 889 | 864 602 |
| 2014 | 65 608 | 13.4 | 3.434 | 66 967 | 921 018 |
| 2015 | 67 889 | 14.3 | 3.561 | 69 309 | 955 968 |
| 2016 | 74 055 | 15.2 | 3.887 | 75 595 | 1 041 071 |
| 2017 | 77 094 | 15.2 | 4.132 | 78 706 | 1 095 446 |
| 2018 | 77 289 | 15.7 | 4.116 | 78 907 | 1 180 609 |
| **Changes from 1990 (%)** | 220.13 | 305.8 | 128.1 | 218.5 | 223.8 |

In road transportation, gasoline, diesel, LPG, natural gas and biodiesel were used as fuel. Road transportation being the major source within the transportation sector contributed 78.9 Mt of $CO_2$ eq. The emissions of $N_2O$ reached 1.23 Mt $CO_2$ eq. and $CH_4$ reached 0.39 Mt $CO_2$ eq. in 2018 (Figure 3.24). Emissions from the consumption of biofuels were taken into consideration for $CH_4$ and $N_2O$ emissions.

**Figure 3.24 GHG emissions for road transportation, 1990-2018**

**Figure 3.25 $CH_4$ and $N_2O$ emissions for road transportation, 1990-2018**

$CO_2$ emissions according to fuel types are illustrated in Figure 3.26. Most important portion of $CO_2$ emission is occurred from diesel fuel consumption, which is about 78% of total emissions of road transportation.

**Figure 3.26 $CO_2$ emission distributions by fuel types, 2018**

### Methodological issues:

$CO_2$ emissions were calculated by multiplying estimated fuel consumption by a default or country-specific, depending on the fuel emission factor i.e. a Tier 1 or Tier 2 method. Country-specific carbon contents for diesel and natural gas are used. $CO_2$ emissions resulting from those fuel types were estimated with Tier 2. $CO_2$ resulting from gasoline, LPG and $CH_4$ and $N_2O$ emissions were estimated by applying default emission factors from the 2006 IPCC Guidelines.

### Collection of Activity Data:

Fuel data used in the road transportation are taken from the national energy balance tables issued by MENR.

### Choice of Emission Factor:

To estimate $CO_2$ emissions, Turkey applies the country specific (diesel, natural gas) and default carbon contents as contained in the 2006 IPCC Guidelines.

### Source-Specific QA/QC and Verification:

Fuel consumption amounts in road transportation provided by the MENR were compared with those of DG of Mining and Petroleum Affairs, reported to IEA.

For the purpose of verifying data documentation; the assumptions and selection criteria on data, EFs and other calculation parameters as well as the completeness of inventory dossiers were checked for correspondence with the 2006 IPCC Guidelines.

In addition, GHG emissions from road transportation were also calculated by using COPERT V program for the years 2016, 2017 and 2018. COPERT V results were compared with the results regarding current methodology (Tier 1, Tier 2) and in terms of $CH_4$, COPERT result was found by far less than results obtained by using current methodology due to usage of default emission factors. Moreover, results obtained from COPERT V were also compared with CRF values of several countries (e.g. Denmark, United Kingdom, Greece, Italy) using COPERT methodology. Considered comparison of implied emission factors, values were found almost in line with each other.

**Table 3.44 Comparison of COPERT and current methodology for GHG emissions from road transportation, 2016-2018**

| | $CO_2$ (kt) | | $CH_4$ (kt) | | $N_2O$ (kt) | | $CO_2$ eq. (kt) | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **Tier 2** | **COPERT** | **Tier 1** | **COPERT** | **Tier 1** | **COPERT** | **Tier 1&2** | **COPERT** |
| 2016 | 74 055 | 74 663 | 15.2 | 4.952 | 3.9 | 2.637 | 75 595 | 75 573 |
| 2017 | 77 094 | 78 701 | 15.2 | 5.677 | 4.1 | 2.807 | 78 706 | 79 679 |
| 2018 | 77 289 | 79 015 | 15.7 | 5.230 | 4.1 | 2.866 | 78 907 | 80 000 |

With this calculation results obtained from COPERT for the years 2016-2018, it is aimed to make calculations regarding previous years. For this purpose, ongoing studies will be taken into account for the next submissions.

**Uncertainties and Time-Series Consistency:**

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 10.05% for liquid fuels.

EF uncertainty for $CO_2$ was considered as 5% (max. value of given range) as indicated in 2006 IPCC Guidelines Vol. 2 page 3.29. For $CH_4$ and $N_2O$ mid value of default uncertainty given in 2006 IPCC Guidelines as 250% were considered.

**Recalculations:**

There is no recalculation for this category.

**Planned Improvement:**

There is no planned improvement for this sector

### 3.2.6.3. Railways (Category 1.A.3.c)

Railway locomotives generally are one of three types: diesel, electric, or steam. Diesel locomotives generally use diesel engines in combination with an alternator or generator to produce the electricity required to power their traction motors. Diesel oil used in railways is taken into consideration. In addition, coal was used for railways from 1990 to 2000. In this context emissions resulted from coal have been calculated. The railways source category was not a key category in 2018.

Figure 3.27 and Figure 3.28 show the total emissions and the emissions of $N_2O$ and $CH_4$ decreasing trends as $CO_2$ equivalents. $CO_2$ equivalent emissions have declined 48.1% since 1990. The amount of emissions calculated for railways is 0.435 Mt $CO_2$ in 2018.

**Table 3.45 GHG emissions from railway, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | TJ |
|---|---|---|---|---|---|
| 1990 | 651 | 0.03 | 0.23 | 721 | 8 670 |
| 1991 | 668 | 0.04 | 0.24 | 740 | 8 923 |
| 1992 | 616 | 0.03 | 0.23 | 685 | 8 287 |
| 1993 | 675 | 0.04 | 0.25 | 751 | 9 110 |
| 1994 | 689 | 0.04 | 0.26 | 768 | 9 338 |
| 1995 | 688 | 0.04 | 0.27 | 768 | 9 348 |
| 1996 | 717 | 0.04 | 0.27 | 799 | 9 697 |
| 1997 | 717 | 0.04 | 0.27 | 799 | 9 717 |
| 1998 | 664 | 0.04 | 0.25 | 740 | 8 900 |
| 1999 | 647 | 0.04 | 0.25 | 722 | 8 780 |
| 2000 | 638 | 0.04 | 0.25 | 713 | 8 686 |
| 2001 | 525 | 0.03 | 0.20 | 587 | 7 150 |
| 2002 | 547 | 0.03 | 0.21 | 612 | 7 453 |
| 2003 | 563 | 0.03 | 0.22 | 629 | 7 670 |
| 2004 | 563 | 0.03 | 0.22 | 629 | 7 670 |
| 2005 | 678 | 0.04 | 0.26 | 757 | 9 230 |
| 2006 | 681 | 0.04 | 0.27 | 761 | 9 273 |
| 2007 | 420 | 0.02 | 0.16 | 470 | 5 724 |
| 2008 | 446 | 0.03 | 0.17 | 499 | 6 080 |
| 2009 | 433 | 0.02 | 0.17 | 484 | 5 900 |
| 2010 | 462 | 0.03 | 0.18 | 517 | 6 296 |
| 2011 | 476 | 0.03 | 0.19 | 532 | 6 485 |
| 2012 | 441 | 0.02 | 0.17 | 492 | 6 001 |
| 2013 | 452 | 0.03 | 0.18 | 505 | 6 154 |
| 2014 | 503 | 0.03 | 0.20 | 562 | 6 843 |
| 2015 | 429 | 0.02 | 0.17 | 480 | 5 848 |
| 2016 | 335 | 0.02 | 0.13 | 374 | 4 561 |
| 2017 | 369 | 0.02 | 0.15 | 413 | 5 105 |
| 2018 | 388 | 0.02 | 0.15 | 435 | 5 373 |
| **Changes from 1990 (%)** | -34.1 | -33.1 | -33.1 | -39.7 | -33.1 |

**Figure 3.27 GHG emissions for railways, 1990-2018**

**Figure 3.28 $CH_4$ and $N_2O$ emissions from railways, 1990-2018**

### Methodological issues:

The IPCC Tier 1&2 approach has been used to estimate $CO_2$, $CH_4$ and $N_2O$ emissions for this subcategory. The Tier 1 approach has been used to estimate $CH_4$ and $N_2O$ emissions.

### Collection of Activity Data:

Energy consumption values for railways were provided by MENR in the form of national energy balance tables.

### Choice of Emission Factor:

To estimate $CO_2$ emissions, Turkey applies the country specific carbon content. Turkey does not modify the emission factors for $CH_4$ and $N_2O$ to take into account engine design parameters.

### Source-Specific QA/QC and Verification:

In terms of calculations made by alternative methods; verification on this category was made by using different AD (passenger/km) and different EFs provided in the document "Structure of Costs and Charges Review – Environmental Costs of Rail Transport Final Report to the Office of Rail Regulation (August 2005)". As a result of the verification, it was observed that the results obtained were very same in each calculation methodology. In addition, fuel consumption values obtained from Energy Balance Table were compared with those reported to IEA.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 2% for liquid fuels.

EF uncertainty for $CO_2$ was derived from 2006 IPCC Guidelines Vol. 2 table 3.4.1 as 1.5% for liquid fuels. For $CH_4$, EF uncertainties were derived as 105% for liquid fuels. For $N_2O$ EFs uncertainties were derived as 142% for liquid fuels.

### Recalculations:

There is no recalculation for this category.

### Planned Improvement:

There is no planned improvement for this category.

## 3.2.6.4. Water-borne navigation (Category 1.A.3.d)

The domestic water borne navigation source category was not a key category in 2018. The data availability is limited in this sub-sector. In domestic water-borne navigation only, diesel and residual fuel oil were consumed as a fuel.

Domestic water-borne navigation contributed 0.93 Mt of $CO_2$ in 2018 while $N_2O$ emissions were 7.54 kt. $CO_2$ eq. and $CH_4$ 2.21 kt. $CO_2$ eq. (Figure 3.29 and 3.30). Overall, between 1990 and 2018 emissions from water-borne navigation increased by 82.9%.

**Table 3.46 GHG emissions from domestic navigation, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | TJ |
|---|---|---|---|---|---|
| 1990 | 504 | 0.05 | 0.01 | 509 | 6 624 |
| 1991 | 537 | 0.05 | 0.01 | 543 | 7 068 |
| 1992 | 632 | 0.06 | 0.02 | 638 | 8 290 |
| 1993 | 657 | 0.06 | 0.02 | 664 | 8 632 |
| 1994 | 617 | 0.06 | 0.02 | 623 | 8 129 |
| 1995 | 719 | 0.07 | 0.02 | 726 | 9 444 |
| 1996 | 692 | 0.06 | 0.02 | 699 | 9 104 |
| 1997 | 691 | 0.06 | 0.02 | 698 | 9 090 |
| 1998 | 718 | 0.07 | 0.02 | 726 | 9 466 |
| 1999 | 652 | 0.06 | 0.02 | 658 | 8 610 |
| 2000 | 617 | 0.06 | 0.02 | 623 | 8 167 |
| 2001 | 792 | 0.07 | 0.02 | 800 | 10 535 |
| 2002 | 813 | 0.08 | 0.02 | 822 | 10 821 |
| 2003 | 881 | 0.08 | 0.02 | 891 | 11 732 |
| 2004 | 1 215 | 0.11 | 0.03 | 1228 | 16 266 |
| 2005 | 1 286 | 0.12 | 0.03 | 1299 | 17 225 |
| 2006 | 1 449 | 0.14 | 0.04 | 1464 | 19 436 |
| 2007 | 1 581 | 0.15 | 0.04 | 1598 | 21 241 |
| 2008 | 1 527 | 0.14 | 0.04 | 1543 | 20 561 |
| 2009 | 1 615 | 0.15 | 0.04 | 1632 | 21 991 |
| 2010 | 1 664 | 0.16 | 0.05 | 1682 | 22 658 |
| 2011 | 2 218 | 0.21 | 0.06 | 2242 | 30 058 |
| 2012 | 1 598 | 0.15 | 0.04 | 1614 | 21 670 |
| 2013 | 1 142 | 0.11 | 0.03 | 1154 | 15 486 |
| 2014 | 1 334 | 0.13 | 0.04 | 1348 | 18 083 |
| 2015 | 1 136 | 0.11 | 0.03 | 1147 | 15 369 |
| 2016 | 960 | 0.09 | 0.03 | 970 | 12 958 |
| 2017 | 934 | 0.09 | 0.03 | 944 | 12 836 |
| 2018 | 921 | 0.09 | 0.03 | 931 | 12 650 |
| **Changes from 1990 (%)** | 82.8 | 90.98 | 90.98 | 82.9 | 90.98 |

**Figure 3.29 GHG emissions from domestic water-borne navigation, 1990-2018**

**Figure 3.30 $CH_4$ and $N_2O$ emissions from domestic water-borne navigation, 1990-2018**

### Methodological issues:

The IPCC Tier 1&2 approach has been used to estimate $CO_2$, $CH_4$ and $N_2O$ emissions for this subcategory. The Tier 1 approach has been used to estimate $CH_4$ and $N_2O$ emissions.

### Collection of Activity Data:

Energy consumption values for domestic navigation were provided by DG of Mining and Petroleum Affairs.

### Choice of emission factor:

For $CO_2$ estimation, country-specific carbon contents were used. The EFs for $CH_4$ and $N_2O$ are taken from IPCC 2006/CORINAIR and set to 7 and 2 kg per TJ respectively.

### Source-Specific QA/QC and Verification:

On the energy balance table provided by the MENR, diesel and fuel oil consumption values were compared with the values provided by MoTI's DG of Merchant Marine, as well as the Annual Activity Report results of Energy Market Regulatory Authority and also with the "Domestic Navigation" fuel consumption amount values which DG of Mining and Petroleum Affairs regularly reports to the IEA.

### Uncertainties and Time-Series Consistency:

The AD were taken from DG of Mining and Petroleum Affairs. AD uncertainties were determined as 15% for liquid fuels.

EF uncertainty for $CO_2$ was considered as 1.5% for liquid fuels as indicated in 2006 IPCC Guidelines Vol. 2 page 3.54. It was considered as 50% for $CH_4$ and 140% for $N_2O$.

### Recalculations:

There is no recalculation for this category.

### Planned Improvement:

There is no planned improvement for this category.

### 3.2.6.5. Pipeline transport (Category 1.A.3.e.i)

This category covers combustion related emissions from the operation of pump stations and maintenance of pipelines. Transport via pipelines includes transport of gases, liquids, slurry and other commodities via pipelines. In Turkey, natural gas is used to carry out operations mentioned above. Pipeline Transport contributed 0.54 Mt of $CO_2$ in 2018. Table 3.47 shows the trend in GHG emissions from pipeline transport.

**Table 3.47 The trend in GHG emissions from pipeline transport, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | TJ |
|---|---|---|---|---|---|
| 1990 | 39 | 0.0007 | 0.00007 | 39 | 705 |
| 1991 | 49 | 0.0009 | 0.00009 | 49 | 875 |
| 1992 | 54 | 0.0010 | 0.00010 | 53 | 962 |
| 1993 | 60 | 0.0011 | 0.00011 | 60 | 1 075 |
| 1994 | 65 | 0.0012 | 0.00012 | 65 | 1 167 |
| 1995 | 83 | 0.0015 | 0.00015 | 83 | 1 489 |
| 1996 | 97 | 0.0017 | 0.00017 | 97 | 1 745 |
| 1997 | 119 | 0.0021 | 0.00021 | 119 | 2 143 |
| 1998 | 123 | 0.0022 | 0.00022 | 123 | 2 221 |
| 1999 | 149 | 0.0027 | 0.00027 | 149 | 2 682 |
| 2000 | 178 | 0.0032 | 0.00032 | 179 | 3 217 |
| 2001 | 197 | 0.0036 | 0.00036 | 197 | 3 553 |
| 2002 | 212 | 0.0038 | 0.00038 | 212 | 3 826 |
| 2003 | 243 | 0.0044 | 0.00044 | 243 | 4 372 |
| 2004 | 240 | 0.0043 | 0.00043 | 240 | 4 317 |
| 2005 | 360 | 0.0065 | 0.00065 | 360 | 6 487 |
| 2006 | 314 | 0.0057 | 0.00057 | 314 | 5 658 |
| 2007 | 335 | 0.0060 | 0.00060 | 335 | 6 030 |
| 2008 | 345 | 0.0062 | 0.00062 | 345 | 6 216 |
| 2009 | 433 | 0.0078 | 0.00078 | 434 | 7 803 |
| 2010 | 386 | 0.0069 | 0.00069 | 387 | 6 945 |
| 2011 | 371 | 0.0066 | 0.00066 | 371 | 6 552 |
| 2012 | 377 | 0.0068 | 0.00068 | 378 | 6 796 |
| 2013 | 557 | 0.0100 | 0.00100 | 557 | 10 025 |
| 2014 | 587 | 0.0106 | 0.00106 | 588 | 10 575 |
| 2015 | 662 | 0.0117 | 0.00117 | 663 | 11 897 |
| 2016 | 617 | 0.0111 | 0.00111 | 617 | 11 073 |
| 2017 | 757 | 0.0136 | 0.00136 | 758 | 13 610 |
| 2018 | 541 | 0.0098 | 0.00098 | 542 | 9 799 |

**Figure 3.31 GHG emissions from pipeline transport, 1990-2018**

### Methodological issues:

In emissions calculation, the 2006 IPCC Guidelines Tier 1&2 approaches are used. $CO_2$ emissions were calculated by multiplying estimated fuel consumption by a country-specific emission factor. $CH_4$ and $N_2O$ emissions were estimated by applying default emission factors from the 2006 IPCC Guidelines.

### Collection of Activity Data:

Fuel consumption data for pipeline transport were provided by Petroleum Pipeline Corporation.

### Choice of emission factor:

For $CO_2$ estimation, country-specific carbon content was used. In Addition, default $CH_4$ (1 kg/TJ) and $N_2O$ (0.1 kg/TJ) emission factors were obtained from the 2006 IPCC Guidelines.

### Source-Specific QA/QC and Verification:

On the energy balance table provided by the MENR, natural gas data were compared with the value provided by Petroleum Pipeline Corporation.

**Recalculations:**

There is no recalculation for this category.

### 3.2.6.6. Off road transportation (Category 1.A.3.e.ii)

GHG emissions from off road vehicles used for agricultural activities is included under 1.A.4.c category.

## 3.2.7. Other sectors (Category 1.A.4)

**Source Category Description:**

The emissions that are included in this category mainly arise from fuel consumption in commercial/institutional, residential and agriculture/forestry/fisheries. The source category (1.A.4.a) and (1.A.4.b) are considered together since they are not presented separately in the national energy balance tables until 2015. The source category 1.A.4.c includes the emission from the agricultural activities but does not include forestry and fisheries.

The source category 1.A.4 is a key category in terms of emission level and emission trend of $CO_2$ from solid, liquid and gaseous fuels in 2018. The source category is also a key category in terms of emission trend of $CH_4$ from solid fuels and biomass.

The share of GHG emissions as $CO_2$ eq. from other sectors in total fuel combustion was 17.2% in 2018 while it was 25.0% in1990. It was 12.1% of total GHG emissions in 2018.

**Table 3.48 Fuel combustion emissions from other sectors (1A4), 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in fuel combustion (1A) category (%) |
|---|---|---|---|---|---|---|
| 1990 | 29 277 | 132.70 | 3.735 | 33 707 | 646 591 | 25.0 |
| 1991 | 30 430 | 133.58 | 3.750 | 34 887 | 658 600 | 25.0 |
| 1992 | 32 537 | 136.70 | 3.774 | 37 079 | 685 301 | 25.4 |
| 1993 | 33 228 | 132.35 | 4.278 | 37 812 | 701 819 | 24.8 |
| 1994 | 29 477 | 121.52 | 4.230 | 33 775 | 667 014 | 22.6 |
| 1995 | 33 297 | 125.61 | 4.312 | 37 722 | 713 541 | 23.2 |
| 1996 | 34 267 | 122.91 | 4.442 | 38 664 | 734 303 | 21.5 |
| 1997 | 36 953 | 127.84 | 4.584 | 41 515 | 771 063 | 21.6 |
| 1998 | 33 429 | 117.52 | 4.485 | 37 704 | 735 920 | 19.7 |
| 1999 | 31 655 | 110.15 | 4.511 | 35 753 | 715 575 | 19.0 |
| 2000 | 33 693 | 107.92 | 4.610 | 37 764 | 737 948 | 18.0 |
| 2001 | 27 686 | 96.27 | 4.377 | 31 397 | 651 581 | 16.2 |
| 2002 | 29 176 | 97.62 | 4.408 | 32 930 | 654 967 | 16.4 |
| 2003 | 32 427 | 99.27 | 4.444 | 36 232 | 688 840 | 16.8 |
| 2004 | 35 645 | 100.92 | 4.674 | 39 561 | 726 309 | 17.9 |
| 2005 | 38 826 | 99.51 | 4.681 | 42 709 | 771 973 | 17.9 |
| 2006 | 38 425 | 94.04 | 4.899 | 42 236 | 770 378 | 16.6 |
| 2007 | 41 335 | 95.38 | 5.233 | 45 279 | 798 938 | 16.0 |
| 2008 | 58 971 | 139.45 | 6.553 | 64 410 | 986 839 | 23.1 |
| 2009 | 65 084 | 157.26 | 6.522 | 70 959 | 1 030 352 | 24.9 |
| 2010 | 62 070 | 152.26 | 6.364 | 67 773 | 973 007 | 24.2 |
| 2011 | 69 279 | 131.55 | 7.006 | 74 656 | 1 078 816 | 24.9 |
| 2012 | 57 465 | 138.11 | 2.241 | 61 586 | 896 880 | 19.7 |
| 2013 | 52 999 | 113.75 | 1.818 | 56 384 | 879 983 | 18.8 |
| 2014 | 52 668 | 112.41 | 2.016 | 56 079 | 876 746 | 17.7 |
| 2015 | 62 494 | 62.76 | 4.242 | 65 327 | 1 010 607 | 19.4 |
| 2016 | 62 413 | 61.56 | 4.190 | 65 201 | 1 020 656 | 18.5 |
| 2017 | 70 272 | 73.39 | 4.310 | 73 391 | 1 112 130 | 19.7 |
| 2018 | 60 102 | 61.31 | 4.141 | 62 869 | 977 068 | 17.2 |

Total GHG emission in 1A4 category decrease 10 522 kt $CO_2$ eq. (14.3% of increase) from 2017 to 2018.

### Methodological Issues:

GHG emissions from 1A4 sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EF are used when available, otherwise default $CO_2$ EF are used. Same $CO_2$ EFs are used from the summary table 3.8. (from 1.A Fuel combustion sector) All $CH_4$ and $N_2O$ EF are also default. The default $CH_4$ and $N_2O$ EF for 1A4 sector are tabulated below.

**Table 3.49 $N_2O$ and $CH_4$ emission factors of fuels used in others sector (1A4).**

| Sub Sectors | Emission Factors $CH_4$ (kg/TJ) | Emission Factors $N_2O$(kg/TJ) | Source |
|---|---|---|---|
| **1A4a sub sector** | | | |
| Coal products | 10 | 1.5 | Table 2.4 |
| LPG | 5 | 0.1 | Table 2.4 |
| Other petroleum products | 10 | 0.6 | Table 2.4 |
| Wood | 300 | 4 | Table 2.4 |
| Natural gas | 5 | 0.1 | Table 2.4 |
| **1A4b, 1A4c sub sectors** | | | |
| Coal products | 300 | 1.5 | Table 2.5 |
| LPG | 5 | 0.1 | Table 2.5 |
| Other petroleum products | 10 | 0.6 | Table 2.5 |
| Wood | 300 | 4 | Table 2.5 |
| Other primary solid biomass | 300 | 4 | Table 2.5 |
| Natural gas | 5 | 0.1 | Table 2.5 |

**Recalculation:**

There is no recalculation in this sector.

### 3.2.7.1. Commercial/Institutional (Category 1.A.4.a)

The fuel consumption of commercial/institutional is not separated in the energy balance tables until 2015, it is given under residential sector for 1990-2014 period. Emissions are given under 1.A.4.a category in 2015 for the first time and they are included under (1.A.4.b) for 1990-2014 periods.

The share of GHG emissions as $CO_2$eq. from 1.A.4.a in total other sector is 21.5% in 201

**Table 3.50 Fuel combustion emissions from 1.A.4.a category, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.4 category (%) |
|---|---|---|---|---|---|---|
| 1990-2014 | IE | IE | IE | IE | IE | IE |
| 2015 | 23 217 | 2.33 | 0.260 | 23 353 | 300 630 | 35.7 |
| 2016 | 22 004 | 2.31 | 0.258 | 22 139 | 298 757 | 34.0 |
| 2017 | 20 540 | 2.01 | 0.190 | 20 647 | 279 840 | 28.1 |
| 2018 | 13 484 | 1.16 | 0.077 | 13 539 | 208 743 | 21.5 |

Total GHG emission in 1.A.4.a category decreased1 7 108 kt $CO_2$ eq. (34.4% of decrease) from 2017 to 2018.

### Methodological Issues:

GHG emissions from 1.A.4.a sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used for emission estimation. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 7.07% for liquid fuels, 14.14% for solid fuels, and 5% for gaseous fuels.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1A4a category was performed on the basis of QA/QC plan. Since only 2015 and 2016 estimation is available for this category, emission trends couldn't be analyzed.

IEF for $CO_2$, $CH_4$, and $N_2O$ are in the range of 2006 IPCC default EFs.

### Recalculation:

There is no recalculation in this sector.

### Planned Improvement:

Prior to 2015 1A4a and 1A4b categories were not separated out in the national energy balance and therefore all of the emissions from these categories were reported under section 1A4b. However, since 2015 they are separated. All relevant institutions are working together in order to overcome this inconsistency problem and allocate 1A4a and 1A4b categories in time series.

### 3.2.7.2. Residential (Category 1.A.4.b)

Residential and commercial/institutional fuel consumptions are not separable in the national energy balance tables until 2015. Therefore, emissions from residential and commercial/institutional category is included under 1.A.4.b for periods 1990-2014. After 2015 only residential sector is covered under 1.A.4.b category. Therefore, there is a sharp decrease in 2015 due to the separation of the commercial and institutional category.

The share of GHG emissions as $CO_2$ eq. from 1.A.4.b category in total other sectors is 61.8% in 2018 while it was 80.8% in 1990.

**Table 3.51 Fuel combustion emissions from residential sector, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.4 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 23 507 | 132.37 | 1.452 | 27 249 | 566 764 | 80.8 |
| 1991 | 24 635 | 133.24 | 1.457 | 28 401 | 578 434 | 81.4 |
| 1992 | 26 727 | 136.37 | 1.475 | 30 575 | 604 918 | 82.5 |
| 1993 | 26 072 | 131.94 | 1.447 | 29 802 | 602 809 | 78.8 |
| 1994 | 22 284 | 121.10 | 1.384 | 25 724 | 567 499 | 76.2 |
| 1995 | 25 958 | 125.19 | 1.408 | 29 507 | 611 993 | 78.2 |
| 1996 | 26 530 | 122.46 | 1.381 | 30 004 | 627 258 | 77.6 |
| 1997 | 28 934 | 127.38 | 1.411 | 32 538 | 660 113 | 78.4 |
| 1998 | 25 485 | 117.06 | 1.342 | 28 811 | 626 011 | 76.4 |
| 1999 | 23 492 | 109.68 | 1.281 | 26 616 | 602 632 | 74.4 |
| 2000 | 25 191 | 107.43 | 1.246 | 28 248 | 620 325 | 74.8 |
| 2001 | 19 551 | 95.80 | 1.158 | 22 291 | 539 029 | 71.0 |
| 2002 | 20 915 | 97.15 | 1.140 | 23 684 | 540 681 | 71.9 |
| 2003 | 24 040 | 98.78 | 1.125 | 26 844 | 572 802 | 74.1 |
| 2004 | 26 632 | 100.40 | 1.108 | 29 472 | 601 603 | 74.5 |
| 2005 | 29 731 | 98.99 | 1.082 | 32 529 | 646 141 | 76.2 |
| 2006 | 28 657 | 93.48 | 1.034 | 31 302 | 635 230 | 74.1 |
| 2007 | 30 694 | 94.77 | 1.022 | 33 368 | 651 714 | 73.7 |
| 2008 | 45 490 | 138.68 | 1.219 | 49 320 | 800 328 | 76.6 |
| 2009 | 51 866 | 156.49 | 1.294 | 56 164 | 847 483 | 79.1 |
| 2010 | 49 119 | 151.51 | 1.241 | 53 277 | 793 813 | 78.6 |
| 2011 | 54 168 | 130.68 | 1.045 | 57 746 | 869 556 | 77.3 |
| 2012 | 54 457 | 137.94 | 1.064 | 58 223 | 855 118 | 94.5 |
| 2013 | 50 649 | 113.61 | 0.934 | 53 767 | 846 990 | 95.4 |
| 2014 | 49 623 | 112.23 | 0.908 | 52 700 | 833 597 | 94.0 |
| 2015 | 30 479 | 59.92 | 0.601 | 32 157 | 587 205 | 49.2 |
| 2016 | 31 721 | 58.75 | 0.572 | 33 360 | 600 881 | 51.2 |
| 2017 | 40 620 | 70.85 | 0.604 | 42 571 | 705 283 | 58.0 |
| 2018 | 37 192 | 59.49 | 0.494 | 38 826 | 636 194 | 61.8 |

Total GHG emission in 1.A.4.b category decreased 3 745 kt $CO_2$ eq. (8.8% of decrease) from 2017 to 2018.

### Methodological Issues:

GHG emissions from 1.A.4.b sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used for emission estimation. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs. GHG emissions from biomass were estimated by using 2006 IPCC default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 7.07% for liquid fuels, 14.14% for solid fuels, 5% for gaseous fuels and 300% for biomass.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1A4b category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

$CO_2$, $CH_4$ and $N_2O$ IEFs for all fuels are in the range of 2006 IPCC Guidelines.

### Recalculation:

There is no recalculation in this sector

### Planned Improvement:

Prior to 2015 1A4a and 1A4b categories were not separated out in the national energy balance and therefore all of the emissions from these categories were reported under section 1A4b. However since 2015 they are separated. Because of that there is a sharp decrease in the amount of emissions in 2015. All relevant institutions are working together in order to overcome this inconsistency problem and allocate 1A4a and 1A4b categories in time series.

### 3.2.7.3. Agriculture/Forestry/Fisheries (Category 1.A.4.c)

**Source Category Description:**

The source category is only including the emission from the consumption of fuel in agricultural activities.

The AD of this sub-category generally keeps consistency during the period 1990-2011, increasing gradually. However, there was a drop in 2012 due to classification problem with diesel oil consumption. Before 2012, diesel fuel was distributed in accordance with the definitions given below:

- Diesel oil (sulfur content up to 10 mg/kg) is used for road transportation
- Rural diesel (maximum sulfur content of 1000 mg/kg) is used in agricultural sector.

Based on this definition, diesel oil consumption in road transportation and agriculture was separated. But "Technical Regulation Notification on Types of Diesel" entered into force by being published on Official Gazette No. 27312 dated 08.07.2009 and restricted diesel oil sulfur content up to 10 mg/kg. The deadline for implementation is extended to April 2011. After April 2011, it is not possible to separate the different use of diesel fuel. So in 2012 energy balance table, some of diesel oil used in agricultural sector is included in road transportation. Due to this fact, a sharp increase in diesel consumption in road transportation and a sharp decrease in fuel consumption of Agriculture/Forestry/Fisheries sector were observed. MENR worked on agricultural association for modeling the agricultural diesel oil consumption. MENR disaggregated the diesel oil consumption data in agriculture sector by a comparison method in which total crop harvested area and petroleum products consumption data of similar countries are weighted to derive an indicator for Turkey.

More than 90% of GHG emissions from agricultural sector is related to off road vehicles. The share of GHG emissions as $CO_2$ eq. from 1.A.4.c category in total other sectors is 16.7% in 2018 while it was 19.2% in 1990.

**Table 3.52 Fuel combustion emissions from agriculture sector, 1990-2018**

| Year | $CO_2$ (kt) | $CH_4$ (kt) | $N_2O$ (kt) | $CO_2$ eq. (kt) | Fuel consumption (TJ) | Share in 1.A.4 category (%) |
|---|---|---|---|---|---|---|
| 1990 | 5 770 | 0.33 | 2.283 | 6 458 | 79 826 | 19.2 |
| 1991 | 5 794 | 0.33 | 2.293 | 6 486 | 80 167 | 18.6 |
| 1992 | 5 810 | 0.33 | 2.299 | 6 503 | 80 383 | 17.5 |
| 1993 | 7 156 | 0.41 | 2.832 | 8 010 | 99 010 | 21.2 |
| 1994 | 7 193 | 0.41 | 2.846 | 8 051 | 99 515 | 23.8 |
| 1995 | 7 340 | 0.42 | 2.904 | 8 216 | 101 548 | 21.8 |
| 1996 | 7 737 | 0.44 | 3.061 | 8 660 | 107 045 | 22.4 |
| 1997 | 8 019 | 0.46 | 3.173 | 8 976 | 110 950 | 21.6 |
| 1998 | 7 944 | 0.46 | 3.143 | 8 892 | 109 909 | 23.6 |
| 1999 | 8 163 | 0.47 | 3.230 | 9 138 | 112 943 | 25.6 |
| 2000 | 8 501 | 0.49 | 3.364 | 9 516 | 117 623 | 25.2 |
| 2001 | 8 135 | 0.47 | 3.219 | 9 106 | 112 553 | 29.0 |
| 2002 | 8 260 | 0.47 | 3.269 | 9 246 | 114 286 | 28.1 |
| 2003 | 8 387 | 0.48 | 3.319 | 9 388 | 116 039 | 25.9 |
| 2004 | 9 013 | 0.52 | 3.567 | 10 089 | 124 705 | 25.5 |
| 2005 | 9 095 | 0.52 | 3.599 | 10 180 | 125 832 | 23.8 |
| 2006 | 9 768 | 0.56 | 3.865 | 10 934 | 135 149 | 25.9 |
| 2007 | 10 641 | 0.61 | 4.211 | 11 911 | 147 224 | 26.3 |
| 2008 | 13 481 | 0.77 | 5.334 | 15 089 | 186 511 | 23.4 |
| 2009 | 13 218 | 0.78 | 5.228 | 14 796 | 182 869 | 20.9 |
| 2010 | 12 951 | 0.74 | 5.123 | 14 496 | 179 194 | 21.4 |
| 2011 | 15 112 | 0.87 | 5.961 | 16 910 | 209 260 | 22.7 |
| 2012 | 3 008 | 0.17 | 1.177 | 3 364 | 41 762 | 5.5 |
| 2013 | 2 350 | 0.14 | 0.885 | 2 617 | 32 992 | 4.6 |
| 2014 | 3 045 | 0.18 | 1.108 | 3 380 | 43 149 | 6.0 |
| 2015 | 8 797 | 0.51 | 3.380 | 9 817 | 122 772 | 15.0 |
| 2016 | 8 688 | 0.51 | 3.360 | 9 702 | 121 018 | 14.9 |
| 2017 | 9 112 | 0.53 | 3.516 | 10 173 | 127 007 | 13.9 |
| 2018 | 9 426 | 0.55 | 3.571 | 10 504 | 132 130 | 16.7 |

Total GHG emission in 1.A.4.c category increased 471 kt $CO_2$ eq. (4.9% of increase) from 2016 to 2017.

### Methodological Issues:

GHG emissions from 1.A.4.c sector were calculated by using 2006 IPCC T1 and T2 approaches by TurkStat. Fuel consumption data were taken from the national energy balance tables in both kt and ktoe units.

Country specific $CO_2$ EFs are used for emission estimation from for both stationary and mobile source categories. $CH_4$ and $N_2O$ emissions from liquid, solid and gaseous fuels have been estimated by using 2006 IPCC default EFs for both stationary and mobile source categories.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 14.14% for liquid fuels and 7% for gaseous fuels.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 page 2.38. Uncertainty values were considered as 7% for $CO_2$ and 100% (mid value in the range) for $CH_4$ and $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.A.4.c category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

$CO_2$, $CH_4$ and $N_2O$ IEFs for all fuels are in the range of 2006 IPCC Guidelines.

### Recalculation:

There is no recalculation in this sector

### Planned Improvement:

MENR worked on agricultural association for modeling the agricultural diesel oil consumption and the disaggregation of diesel oil consumption was achieved in 2015 national energy balance tables. However national energy balance tables are not in time series therefore the allocation problem still exists between 2012 and 2014. All relevant institutions are working together and make planning in order to overcome this inconsistency problem.

## 3.2.8. Other (Category 1.A.5)

No other sectors were covered under energy sector. Emissions from fuel delivered to the military is included under category 1.A.4.b for 1990-2014 periods and 1.A.4.a (for stationary) and 1.A.3 (for mobile) since 2015.

## 3.3. Fugitive Emission from Fuels (Category 1.B)

### Source Category Description:

Fugitive emissions from extraction, processing, storage and transport of fossil fuels were covered under this category. $CH_4$ emission from coal mining, $CH_4$, $CO_2$, $N_2O$ and NMVOC emissions from exploration, production/processing, transport/transmission, refining and storage of oil and natural gas were covered.

**Table 3.53 Fugitive emissions from fuels, 1990-2018**

(kt)

| Year | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ eq. |
|---|---|---|---|---|
| 1990 | 220 | 160 | 0.0031 | 4 222 |
| 1991 | 263 | 153 | 0.0037 | 4 098 |
| 1992 | 254 | 153 | 0.0035 | 4 081 |
| 1993 | 231 | 150 | 0.0032 | 3 994 |
| 1994 | 219 | 146 | 0.0031 | 3 876 |
| 1995 | 209 | 144 | 0.0029 | 3 817 |
| 1996 | 208 | 143 | 0.0029 | 3 789 |
| 1997 | 206 | 157 | 0.0029 | 4 136 |
| 1998 | 194 | 174 | 0.0027 | 4 546 |
| 1999 | 178 | 215 | 0.0025 | 5 544 |
| 2000 | 168 | 229 | 0.0023 | 5 890 |
| 2001 | 155 | 213 | 0.0021 | 5 481 |
| 2002 | 148 | 195 | 0.0020 | 5 028 |
| 2003 | 145 | 189 | 0.0020 | 4 861 |
| 2004 | 140 | 184 | 0.0019 | 4 751 |
| 2005 | 142 | 211 | 0.0019 | 5 420 |
| 2006 | 135 | 226 | 0.0018 | 5 791 |
| 2007 | 133 | 302 | 0.0018 | 7 683 |
| 2008 | 135 | 321 | 0.0018 | 8 167 |
| 2009 | 138 | 311 | 0.0019 | 7 904 |
| 2010 | 156 | 314 | 0.0021 | 8 018 |
| 2011 | 151 | 345 | 0.0021 | 8 774 |
| 2012 | 144 | 355 | 0.0020 | 9 027 |
| 2013 | 146 | 315 | 0.0020 | 8 021 |
| 2014 | 145 | 386 | 0.0020 | 9 786 |
| 2015 | 155 | 198 | 0.0021 | 5 117 |
| 2016 | 158 | 320 | 0.0022 | 8 158 |
| 2017 | 157 | 246 | 0.0021 | 6 311 |
| 2018 | 174 | 299 | 0.0024 | 7 662 |

$CO_2$ and $CH_4$ are the main fugitive emissions in this category. $CH_4$ was emitted mainly from coal mining while $CO_2$ was emitted from venting and flaring. Fugitive emissions as $CO_2$ eq. have become 6311 ktons in 2017. 48% of fugitive emissions as $CO_2$ eq. were from oil and gas systems and 52% were from solid fuels in the same year.

**Table 3.54 Fugitive emissions from fuels by subcategory, 1990-2018**
**(kt $CO_2$ eq.)**

| Year | Total | Solid fuels | Oil and natural gas |
|---|---|---|---|
| 1990 | 4 510 | 3 598 | 912 |
| 1991 | 4 300 | 3 219 | 1 080 |
| 1992 | 4 245 | 3 177 | 1 067 |
| 1993 | 4 133 | 3 114 | 1 020 |
| 1994 | 3 999 | 2 998 | 1 001 |
| 1995 | 4 023 | 2 985 | 1 038 |
| 1996 | 4 060 | 2 967 | 1 092 |
| 1997 | 4 364 | 3 187 | 1 177 |
| 1998 | 4 745 | 3 565 | 1 180 |
| 1999 | 5 720 | 4 481 | 1 239 |
| 2000 | 6 145 | 4 836 | 1 309 |
| 2001 | 5 702 | 4 387 | 1 315 |
| 2002 | 5 418 | 4 059 | 1 358 |
| 2003 | 5 190 | 3 664 | 1 526 |
| 2004 | 5 134 | 3 568 | 1 566 |
| 2005 | 5 752 | 3 941 | 1 811 |
| 2006 | 6 086 | 4 119 | 1 966 |
| 2007 | 7 949 | 5 725 | 2 224 |
| 2008 | 8 410 | 6 118 | 2 291 |
| 2009 | 8 128 | 6 061 | 2 067 |
| 2010 | 8 226 | 6 151 | 2 075 |
| 2011 | 9 065 | 6 662 | 2 403 |
| 2012 | 9 381 | 6 851 | 2 530 |
| 2013 | 8 524 | 6 324 | 2 199 |
| 2014 | 10 216 | 7 318 | 2 898 |
| 2015 | 5 496 | 2 733 | 2 763 |
| 2016 | 8 596 | 5 896 | 2 700 |
| 2017 | 6 699 | 3 681 | 3 017 |
| 2018 | 7 662 | 4 885 | 2 777 |

### Methodological Issues:

GHG emissions from 1.B sector were calculated by using 2006 IPCC T1 approaches by TurkStat. Domestic production data for coal, oil and natural gas were taken from the national energy balance tables in kt. MENR provided domestic coal production in underground and surface mining details. Pipeline transmission amount of oil and natural gas and natural gas storage were provided by, Petroleum Pipeline Company (BOTAŞ) (which is state own enterprise and authority for crude oil and natural gas transportation and pipeline operation). Petroleum refining data were taken from Turkish Petroleum Refineries Co. (TÜPRAŞ). For LPG and gasoline distribution, consumption values presented in the national energy balance tables were used as AD.

Fugitive GHG emissions were estimated by using 2006 IPCC default EFs.

### 3.3.1. Solid fuels (Category 1.B.1)

#### Source Category Description:

This source category covers $CH_4$ emissions which occur during the surface and underground extraction of solid fuels and post-mining activities as well as abandoned underground mines. The emissions due to combustions of those fuels to support production activities is not included in this section. Under this category only fugitive $CH_4$emissions are calculated.

Fugitive emissions from coal mining has increased to 4 885 t $CO_2$ eq. in 2018 due to the increase in the underground mining activities with respect to previous year.

**Table 3.55 Fugitive emissions from solid fuels, 1990-2018**

(kt)

| Year | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ eq. |
|---|---|---|---|---|
| 1990 | NE | 144 | NO,NE | 3 598 |
| 1991 | NE | 129 | NO,NE | 3 219 |
| 1992 | NE | 127 | NO,NE | 3 177 |
| 1993 | NE | 125 | NO,NE | 3 114 |
| 1994 | NE | 120 | NO,NE | 2 998 |
| 1995 | NE | 119 | NO,NE | 2 985 |
| 1996 | NE | 119 | NO,NE | 2 967 |
| 1997 | NE | 127 | NO,NE | 3 187 |
| 1998 | NE | 143 | NO,NE | 3 565 |
| 1999 | NE | 179 | NO,NE | 4 481 |
| 2000 | NE | 193 | NO,NE | 4 836 |
| 2001 | NE | 175 | NO,NE | 4 387 |
| 2002 | NE | 162 | NO,NE | 4 059 |
| 2003 | NE | 147 | NO,NE | 3 664 |
| 2004 | NE | 143 | NO,NE | 3 568 |
| 2005 | NE | 158 | NO,NE | 3 941 |
| 2006 | NE | 165 | NO,NE | 4 119 |
| 2007 | NE | 229 | NO,NE | 5 725 |
| 2008 | NE | 245 | NO,NE | 6 118 |
| 2009 | NE | 242 | NO,NE | 6 061 |
| 2010 | NE | 246 | NO,NE | 6 151 |
| 2011 | NE | 266 | NO,NE | 6 662 |
| 2012 | NE | 274 | NO,NE | 6 851 |
| 2013 | NE | 253 | NO,NE | 6 324 |
| 2014 | NE | 293 | NO,NE | 7 318 |
| 2015 | NE | 109 | NO,NE | 2 733 |
| 2016 | NE | 236 | NO,NE | 5 896 |
| 2017 | NE | 147 | NO,NE | 3 681 |
| 2018 | NE | 195 | NO,NE | 4 885 |

In 2018 the amount of coal mined have been increased by 13.3% and become 83 937 ktons. In 2018, the emissions from coal mining activities have been increased by 37.7% and become 3294 ktons $CO_2$ eq. This is due to the decrease in the share of underground mines. In 2016 the share of underground mines was 16.5% whereas it is 7.1% in 2017.

**Figure 3.32 Domestic coal production 1990-2018**

**Figure 3.33 $CH_4$ emissions from coal mining, 1990-2018**

**Table 3.56 Fugitive emissions from abandoned coal mines,1990-2018**

(kt)

| Year | $CO_2$ | $CH_4$ | $CO_2$ eq. |
|---|---|---|---|
| 1990 | NE | 11.5 | 288 |
| 1991 | NE | 8.1 | 201 |
| 1992 | NE | 6.6 | 164 |
| 1993 | NE | 5.6 | 140 |
| 1994 | NE | 4.9 | 122 |
| 1995 | NE | 8.2 | 205 |
| 1996 | NE | 10.8 | 271 |
| 1997 | NE | 9.1 | 229 |
| 1998 | NE | 8.0 | 199 |
| 1999 | NE | 7.1 | 177 |
| 2000 | NE | 10.2 | 256 |
| 2001 | NE | 8.9 | 222 |
| 2002 | NE | 15.6 | 389 |
| 2003 | NE | 13.2 | 329 |
| 2004 | NE | 15.3 | 384 |
| 2005 | NE | 13.3 | 332 |
| 2006 | NE | 11.8 | 295 |
| 2007 | NE | 10.6 | 266 |
| 2008 | NE | 9.7 | 243 |
| 2009 | NE | 9.0 | 224 |
| 2010 | NE | 8.3 | 208 |
| 2011 | NE | 11.6 | 291 |
| 2012 | NE | 14.2 | 355 |
| 2013 | NE | 20.1 | 503 |
| 2014 | NE | 17.2 | 430 |
| 2015 | NE | 15.2 | 380 |
| 2016 | NE | 17.5 | 438 |
| 2017 | NE | 15.5 | 387 |
| 2018 | NE | 14.0 | 350 |

### Methodological Issues:

GHG emissions from 1.B.1 sector were calculated by using 2006 IPCC T1 approaches by TurkStat. Domestic coal production data were taken from the national energy balance tables. MENR provided domestic coal production in underground and surface mining details.

Fugitive GHG emissions from coal mines were estimated by using 2006 IPCC default EFs. Both mining and post mining fugitive emissions from underground and surface mines were estimated.

The fugitive emissions from abandoned underground mines are calculated with tier 2 methodology shown below.

Methane Emissions = (Number of coal mines abandoned remaining unflooded) x (Fraction of gassy mines) x (Average emission rate) x (Emission factor) x (Conversion factor) See eqn. 4.1.11 in 2006 IPCC Guidelines Volume 1. All parameter used in this equation are default values.

Fraction of gassy mines is 100%

Average emission rate is 5.735 $m^3$/year

Emission factor is calculated as EF = $(1+aT)^b$ where a and b are default values for either lignite or hard coal and T is the years elapsed since abandonment. The coefficients used in the calculations is given below.

**Table 3.57 Coefficients used in the calculation of abandoned coal mines methane emission**

| Coal type | a | b |
|---|---|---|
| Hard coal | 3.72 | -0.42 |
| Lignite | 0.27 | -1 |

(Source: see eqn 4.1.12 and table 4.1.9 in 2006 IPCC Guidelines Volume 1)

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 16.6% for coal production.

Default EFs uncertainty for coal mining was taken from 2006 IPCC Guidelines Vol.2 Table 4.1.2 and Table 4.1.4. $CH_4$EFs uncertainty value was determined as 557%.

### Source-Specific QA/QC and Verification:

Quality control for 1.B.1 category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

$CH_4$IEFs are in the range of 2006 IPCC Guidelines.

### Recalculation:

There is no recalculation in this sector

### Planned Improvement:

Since the category is a key category in terms of emission trend of $CH_4$, the tiers in $CH_4$ estimation needs to be increased. Detailed investigation has been performed to find out the availability of country specific or basin specific EFs within both general directorates for lignite and hard coal structured under the

MENR, namely, DG Turkish Lignite Enterprises and DG Turkish Hard Coal Enterprises. However, information for the generation of country-specific EFs are not available centrally in those coal authorities. Therefore, it is necessary to communicate and cooperate with mining enterprises directly to search the availability of required information for T2 estimation of $CH_4$.

### 3.3.2. Oil and natural gas (Category 1.B.2)

#### Source Category Description:

This source category covers fugitive $CO_2$, $N_2O$, $CH_4$ emissions from exploration, production (processing), transport (transmission), refining and storage of oil and natural gas. Three sub-source categories, oil (1.B.2.a), natural gas (1.B.2.b) and venting and flaring (1.B.2.c) were covered under this category.

This source category is a key category in terms of emission level and trend of $CH_4$emission. $CO_2$ emissions are mainly coming from oil production. About 95% of $CO_2$ emissions from oil and gas systems are venting and flaring emissions during oil extraction and production. $CH_4$ emissions are mainly coming from oil production and pipeline transmission and distribution of natural gas. In parallel to the increase in natural gas transmission and distribution, the greenhouse gas emissions in 1.B.2 category has increased from 912 kt CO2 eq. in 1990 to 2 777 kt in 2018.

**Table 3.58 Fugitive emissions from oil and natural gas systems,1990-2018**

(kt)

| Year | $CO_2$ | $CH_4$ | $N_2O$ | $CO_2$ eq. |
|---|---|---|---|---|
| 1990 | 220 | 27.6 | 0.0031 | 912 |
| 1991 | 263 | 32.6 | 0.0037 | 1 080 |
| 1992 | 254 | 32.5 | 0.0035 | 1 067 |
| 1993 | 231 | 31.5 | 0.0032 | 1 020 |
| 1994 | 219 | 31.2 | 0.0031 | 1 001 |
| 1995 | 209 | 33.1 | 0.0029 | 1 038 |
| 1996 | 208 | 35.3 | 0.0029 | 1 092 |
| 1997 | 206 | 38.8 | 0.0029 | 1 177 |
| 1998 | 194 | 39.4 | 0.0027 | 1 180 |
| 1999 | 178 | 42.4 | 0.0025 | 1 239 |
| 2000 | 168 | 45.6 | 0.0023 | 1 309 |
| 2001 | 155 | 46.4 | 0.0021 | 1 315 |
| 2002 | 148 | 48.4 | 0.0020 | 1 358 |
| 2003 | 145 | 55.2 | 0.0020 | 1 526 |
| 2004 | 140 | 57.0 | 0.0019 | 1 566 |
| 2005 | 142 | 66.8 | 0.0019 | 1 811 |
| 2006 | 135 | 73.2 | 0.0018 | 1 966 |
| 2007 | 133 | 83.6 | 0.0018 | 2 224 |
| 2008 | 135 | 86.2 | 0.0018 | 2 291 |
| 2009 | 138 | 77.1 | 0.0019 | 2 067 |
| 2010 | 156 | 76.7 | 0.0021 | 2 075 |
| 2011 | 151 | 90.1 | 0.0021 | 2 403 |
| 2012 | 144 | 95.4 | 0.0020 | 2 530 |
| 2013 | 146 | 82.1 | 0.0020 | 2 199 |
| 2014 | 145 | 110.1 | 0.0020 | 2 898 |
| 2015 | 155 | 104.3 | 0.0021 | 2 763 |
| 2016 | 158 | 101.7 | 0.0022 | 2 700 |
| 2017 | 157 | 114.4 | 0.0021 | 3 017 |
| 2018 | 174 | 104.1 | 0.0024 | 2 777 |

**Figure 3.34 Oil production, 1990–2018**

**Figure 3.35 Natural gas production, 1990-2018**

**Figure 3.36 Natural gas transmission by pipeline, 1990-2018**

**Figure 3.37 Fugitive emissions from oil and gas system, 1990-2018**

### Methodological Issues:

GHG emissions from 1.B.2 sector were calculated by using 2006 IPCC T1 approaches by TurkStat.

Domestic production data for oil and natural gas were taken from the national energy balance tables in kt. Pipeline transmission amount of oil and natural gas and data related to storage of natural gas were provided by BOTAŞ, Petroleum Pipeline Company (which is a state own enterprise and authority for crude oil and natural gas transportation and pipeline operations). Petroleum refining data were taken from Turkish Petroleum Refineries Co. (TÜPRAŞ). For LPG and gasoline distribution, consumption values for those fuels were used from the national energy balance tables.

Fugitive GHG emissions from oil and natural gas systems were estimated by using 2006 IPCC Guidelines default EFs. Since the category is a key category in terms of emission level and trend of $CH_4$, the tiers in estimating $CH_4$ emission need to be increased. Detailed investigation has been performed to find out the availability of country specific EF. It is necessary to communicate and cooperate with related authorities directly to search the availability of required information for Tier 2 estimation of $CH_4$. It is planned to continue with investigations.

### Uncertainties and Time-Series Consistency:

The AD were taken from the national energy balance tables. Uncertainties in the AD were determined by experts of MENR. AD uncertainties were determined as 7% for oil and gas systems.

Default EFs uncertainty for oil and gas systems was taken from 2006 IPCC Guidelines Vol.2 Table 4.2.4. Oil and gas systems EFs uncertainty values were determined as 334% for $CO_2$, 356% for $CH_4$, and 224% for $N_2O$.

### Source-Specific QA/QC and Verification:

Quality control for 1.B.2 category was performed on the basis of QA/QC plan. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

IEFs are controlled and they are all in the range of 2006 IPCC default values.

### Recalculation:

There is no recalculation in this category.

### Planned Improvement:

In order to increase the tiers for $CH_4$ emission estimation, availability of detailed information have been searched. It is planned to continue the investigation to find out the availability or possibility of availability of appropriate data for higher tiers.

## 3.4. $CO_2$ Transport and Storage (Category 1.C)

### Source Category Description:

This source category covers only fugitive $CO_2$ from pipeline transportation of $CO_2$. This source category is not a key category. $CO_2$ emissions were calculated on the basis of pipeline length as 0.126 kt for whole 1990-2017 period.

### Methodological Issues:

$CO_2$ emissions from 1C sector were calculated by using 2006 IPCC Tier 1 approaches by TurkStat. Pipeline length was obtained from Turkish Petroleum Incorporation. Pipeline length has not changed with respect to the previous inventory year. Fugitive $CO_2$ emissions from CRF category 1C were estimated by using 2006 IPCC Guidelines default EFs.

### Uncertainties and Time-Series Consistency:

The AD were taken from Turkish Petroleum Incorporation. AD uncertainty was considered 2% as indicated in Table 2.15 of 2006 IPCC Guidelines Vol.2. Since AD have been taken directly from the company uncertainty level for survey data were considered and to be conservative the maximum uncertainty value was used.

EFs uncertainty was taken from 2006 IPCC Guidelines Vol.2 Table 5.2. Uncertainty values were considered as 200% for $CO_2$.

### Recalculation:

There is no recalculation in this category.

### Planned Improvement:

There is no planned improvement for this category.

# 4. INDUSTRIAL PROCESSES AND PRODUCT USE (CRF Sector 2)

## 4.1. Sector Overview

The GHG emissions from industrial processes and product use are released as a result of manufacturing processes. It means this category includes only emissions from processes and not from fuel combustion used to supply energy for carrying out the processes. For that reason, emissions from industrial processes are referred to as non-combustion.

Industrial processes whose contribution to $CO_2$ emissions were identified as key category are production of cement, lime, and iron and steel, as well as other process uses of carbonates in different industrial activities. PFC emissions from aluminium production and HFCs from product uses as ODS substitutes are also considered key categories.

GHG emissions from industrial processes and product use contributed 12.5% to the total anthropogenic GHG emissions in Turkey in 2018 (Table 4.1), in total 65 204 kt $CO_2$ eq.

**Table 4.1 Industrial processes and product use sector emissions, 2018**

**(kt $CO_2$ eq.)**

| GHG sources and sink categories | $CO_2$ | $CH_4$ | $N_2O$ | HFCs /PFCs/$SF_6$ | Total |
|---|---|---|---|---|---|
| **Industrial processes and product use** | 58 117 | 17 | 1 823 | 5 247 | 65 204 |
| A. Mineral industry | 43 819 | NA | NA | NA | 43 819 |
| B. Chemical industry | 1 270 | NO,IE,NA | 1 823 | NA | 3 093 |
| C. Metal industry | 12 822 | 17 | NA | 37 | 12 876 |
| D. Non-energy products from fuels and solvent use | 206 | NA,NE | NA,NE | NA | 206 |
| E. Electronic Industry | NA | NA | NA | 57 | 57 |
| F. Product uses as ODS substitutes | NA | NA | NA | 5 082 | 5 082 |
| G. Other product manufacture and use | NA | NA | NA | 71 | 71 |
| H. Other | NE | NE | NA | NE,IE | NE,IE |

The most important GHG emission sources of IPPU in 2018 were $CO_2$ emissions from cement production and iron and steel production, with 7.2% and 2.2% shares of the total national GHG emissions, respectively.

The mineral industry contributed 67.2% of the sector's emissions, the metal industry contributed 19.7%, product uses as ODS substitutes contributed 7.8%, while the chemical industry contributed 4.7%.

The main gas emitted by the IPPU sector in 2018 was $CO_2$, contributing 89.7% (56 980 kt) of the sector emissions in 2018. HFCs, PFCs and $SF_6$ contributed 8.2% (5 232 kt $CO_2$ eq.) while the share of $N_2O$ emissions was 2% (1 263 kt $CO_2$eq.) and $CH_4$ emissions was 0.03% (16.3 kt $CO_2$ eq.).

**Figure 4.1 Emissions from industrial processes and product use by subsector, 1990–2018**

Total emissions from industrial process and product use increased by 186% between 1990 (22 836 kt $CO_2$ eq.) and 2018, and increased 2.5% between 2017 and 2018. The increases in sectoral emissions observed over the longer term are principally due to growth in emissions associated with the mineral industry, predominantly cement production, and metal industry, primarily iron and steel production. The increases in emissions in these sectors are because of the industrial growth and the increased demand for construction materials. Each source category's contribution to total emissions and to sectoral trends within the IPPU sector between 1990 and 2018 is shown in Figure 4.1.

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

Non-fuel $CO_2$ emissions from cement and lime production and from limestone and dolomite use, glass production as well as emissions from ceramics production, soda ash use and non-metallurgical magnesia production are reported in this category.

Figure 4.2 depicts the share of $CO_2$ emissions in this category. The major share (84.5%) results from 2A1 cement production, 6.4% from 2A3 lime production and 7.7% from 2A4 other process uses of carbonates. Glass production is responsible for 1.5% of emissions in the mineral industry.

**Figure 4.2 Share of $CO_2$ emissions from mineral production, 2018**

## 4.2.1. Cement production (Category 2.A.1)

### Source Category Description:

Cement production causes $CO_2$ emissions due to calcination reaction of limestone during production and these emissions are reported under 2.A.1 CRF category. Moreover, cement production is an energy intensive process. Heating up the kiln with its load to such a high temperature is extremely energy consuming. Most of the kilns in Turkey uses coal, petroleum coke, lignite as the primary energy source. The emissions due to combusting of these fuels to heat up the kilns are included in 1.A.2f CRF category. The table below shows allocation of cement production emissions in the CRF categories.

**Table 4.2 Allocations of cement production emissions**

| CRF category | Emission source |
|---|---|
| CRF 2.A.1 | Emissions from calcination reactions in the kilns |
| CRF 1.A.2f | Emissions from fuel consuming for the energy demand of the production plant. |

In cement production, limestone is fed to the cement kiln and heated up to 1400-1500 °C to produce lime. At this temperature calcium carbonate ($CaCO_3$) breaks into lime (CaO) and carbon dioxide ($CO_2$). The reaction is shown below.

$$CaCO_3 \rightarrow CaO + CO_2$$

Then, silica containing materials are combined with the lime to make the clinker. Clinker is the most important intermediate product. It is also traded as a commodity. Cement is produced by mixing the clinker with small amount of gypsum and potentially other materials (e.g slag) and grinding it. All the $CO_2$ emissions are released from the kilns during the clinker production step.

Figure 4.3 below shows the trend at clinker production and the related $CO_2$ emissions between 1990 and 2018.

**Figure 4.3 Trend at clinker, cement production and related $CO_2$ emissions, 1990-2018**

Turkey started cement production in 1911 and Turkey was a cement importer till 1970s. Turkey started exporting cement in 1978. By 2018, Turkey is the Europe's biggest cement producer with its 75 million tons of clinker production capacity and the production plants are distributed all over the country because transportation costs in the cement sector is quite high. In Turkey mostly portland cement is produced. Slag cement, puzzolan added cement and their modifications are also produced.

As can be seen from the figures above, $CO_2$ emissions increased by 254% between 1990 and 2018. Except some minor reductions in 2001 due to Turkey's economic recessions and in 2015 due to conflict at Turkey's southern neighborhood (Syria and Iraq), cement industry showed a continuous growth in general. Construction sector and cement export are the strongest drivers in the cement sector. In 2015, since Turkish construction industry slowed down in recent years and cement export is decreased due to conflicts in the nearby countries, clinker production was decreased by 2.6% with respect to 2014. In

2018 clinker production was 70 344 ktons (94% capacity is used) and it caused 37 026 kt of $CO_2$ emission.

### Methodological Issues:

Estimation of $CO_2$ emissions is accomplished by applying a country-specific EF, in tonnes of $CO_2$ released per tonnes of clinker produced, to the annual national clinker output, corrected with the fraction of clinker that is lost from the kiln in the form of cement kiln dust (CKD). This is the T2 methodology in the 2006 IPCC Guidelines as illustrated below.

$$CO_2\ emissions = M_{Cl} * EF_{Cl} * CF_{CKD}$$

Where:

$CO_2$ Emissions = emissions of $CO_2$ from cement production, tonnes

$M_{cl}$ = weight (mass) of clinker produced, tonnes

$EF_{cl}$ = emission factor for clinker, tonnes $CO_2$/tonne clinker

$CF_{ckd}$ = emissions correction factor for CKD, dimensionless

**Collection of activity data**

There are 54 cement plants in Turkey spread all over Turkey. Most of the cement plants in Turkey are members of Turkish Cement Manufacturers Assembly (TCMA) and they report their activity data to TCMA on monthly basis and TCMA publish the data as industry specific statistics on their website. For those plants who are not a member of TCMA, their activity data is estimated by TCMA. Annual amount of national clinker production of Turkey is gathered from the clinker production statistics of the TCMA website.

**Choice of emission factor**

In the 2016 inventory, data for the carbonate content in clinker was gathered from the production plants for the years 1990-2015. It was determined that the average weight percentage of CaO varies between 64% - 66% throughout the time series and was 65.8% in 2015. The corresponding EF in 2015 is 0.515913. This study reveals that CaO content does not vary thorough out the years and was not iterated again for the latest inventory. Turkey applies the IPCC default CKD correction factor of 1.02. In the following table, all the activity data and emission factors used for the emission calculation in the time series are shown. In addition, annual $CO_2$ emissions from clinker production are tabulated.

**Table 4.3 $CO_2$ emissions from cement production, 1990-2018**

| Year | Clinker Production (kt) | Cement Production (kt) | CaO Content (%) | $CO_2$ EF | CKD | $CO_2$ Emission (kt) |
|---|---|---|---|---|---|---|
| 1990 | 20 252 | 24 416 | 64.4 | 0.506 | 1.02 | 10 445 |
| 1991 | 23 153 | 26 261 | 64.9 | 0.509 | 1.02 | 12 021 |
| 1992 | 25 489 | 28 607 | 65.0 | 0.510 | 1.02 | 13 265 |
| 1993 | 24 941 | 31 366 | 65.4 | 0.513 | 1.02 | 13 049 |
| 1994 | 25 880 | 29 515 | 65.1 | 0.511 | 1.02 | 13 493 |
| 1995 | 27 094 | 33 140 | 65.2 | 0.511 | 1.02 | 14 133 |
| 1996 | 27 852 | 35 233 | 65.8 | 0.516 | 1.02 | 14 662 |
| 1997 | 28 706 | 36 007 | 65.7 | 0.516 | 1.02 | 15 105 |
| 1998 | 29 148 | 37 488 | 65.5 | 0.514 | 1.02 | 15 292 |
| 1999 | 27 966 | 34 817 | 65.2 | 0.511 | 1.02 | 14 590 |
| 2000 | 28 950 | 35 953 | 65.5 | 0.514 | 1.02 | 15 184 |
| 2001 | 28 746 | 29 959 | 65.6 | 0.515 | 1.02 | 15 087 |
| 2002 | 29 499 | 32 758 | 65.7 | 0.516 | 1.02 | 15 513 |
| 2003 | 30 419 | 35 095 | 65.8 | 0.516 | 1.02 | 16 022 |
| 2004 | 32 779 | 38 796 | 65.6 | 0.515 | 1.02 | 17 207 |
| 2005 | 36 382 | 42 787 | 65.6 | 0.515 | 1.02 | 19 117 |
| 2006 | 39 569 | 49 100 | 65.8 | 0.516 | 1.02 | 20 841 |
| 2007 | 43 174 | 51 226 | 65.9 | 0.517 | 1.02 | 22 780 |
| 2008 | 47 095 | 54 362 | 65.9 | 0.517 | 1.02 | 24 837 |
| 2009 | 50 436 | 59 273 | 65.8 | 0.516 | 1.02 | 26 558 |
| 2010 | 55 485 | 66 027 | 65.9 | 0.517 | 1.02 | 29 284 |
| 2011 | 57 823 | 67 805 | 66.0 | 0.518 | 1.02 | 30 527 |
| 2012 | 57 758 | 67 519 | 65.9 | 0.517 | 1.02 | 30 449 |
| 2013 | 62 736 | 74 437 | 65.7 | 0.516 | 1.02 | 32 995 |
| 2014 | 63 642 | 72 639 | 65.7 | 0.516 | 1.02 | 33 472 |
| 2015 | 61 971 | 71 419 | 65.8 | 0.516 | 1.02 | 32 619 |
| 2016 | 67 856 | 75 403 | 65.8 | 0.516 | 1.02 | 35 716 |
| 2017 | 70 813 | 80 552 | 65,8 | 0.516 | 1.02 | 37 272 |
| 2018 | 70 344 | 72 544 | 65.8 | 0.516 | 1.02 | 37 026 |

### Uncertainties and Time-Series Consistency:

The uncertainty value of the AD was estimated to be ±5% with error propagation equations. Although aggregated plant production data was used for the calculation, plant specific production data also gathered and their summation is compared with the aggregated production data that TCMA supplied and it is found that they are close for 2015. The uncertainty value of the EF is 2% due to chemical analysis of clinker to determine CaO percentage and default factor used for CKD. Moreover, Monte Carlo analysis has been carried out for the $CO_2$ emissions from cement production again for this submission

and it resulted with -5.35% to +5.37% combined uncertainty. Further information about Monte Carlo analysis of cement production can be seen in Uncertainty chapter (Annex 2).

**Source-Specific QA/QC and Verification:**

Clinker production data is gathered by the TCMA and reported monthly on their website. However, TCMA do not report on CaO contents in the clinker. The annual average CaO contents of all the cement factories are asked by a questionnaire and meanwhile clinker production amount of the factories is also asked for quality assurance purpose in 2017. Details of this study can be found in inventory submitted in 2018. In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

Moreover, the clinker production data gathered from the TCMA are compared to the PRODCOM (Turkish national industrial production statistics). They are found to be consistent. In 2018, one of the clinker production plant visited and discussed on CKD data. According to the researches, due to the production system is sealed, it was assumed there is no kiln dust. So, in its emission calculation, plants do not report CKD to the Ministry of Environment and Urbanization. However, there is no enough information for other plant

**Recalculation:**

There is no recalculation in this sector for the 2017 inventory year.

**Planned improvements:**

Turkey recently made improvements in the representativeness of the country specific carbonate content of the clinker. In 2018, one of the clinker production plant visited and discussed on CKD data. According to the researches, due to the production system is sealed, it was assumed there is no kiln dust. So, in its emission calculation, plants do not report CKD to the Ministry of Environment and Urbanization. However, there is no enough information for other plants, CKD is still assumed as 2% of the total emissions. In the next years it is planned to collect data on plant specific CKD.

### 4.2.2. Lime production (Category 2.A.2)

**Source Category Description:**

The word lime refers to product obtained by calcining the limestone. The production of lime involves a series of steps which include quarrying the raw material, crushing and sizing, and calcination. Limestone

is a naturally occurring and abundant rock that consists of high levels of calcium carbonate (and maybe some magnesium carbonate). Lime production begins by extracting limestone from quarries. Then limestone enters into a crusher and screened to obtain small pieces of limestone. Then the crushed and sized limestone particles are heated in the kiln. Heating up the limestone causes the calcination of the calcium carbonate molecules (and magnesium carbonate molecules if any). $CO_2$ is generated during the calcination stage, when limestone ($CaCO_3$) are burned at high temperature (900-1200°C) in a kiln to produce quicklime (CaO) and $CO_2$ is released in the atmosphere. Magnesium carbonate ($MgCO_3$) breaks into MgO and $CO_2$ in the same manner. The calcination reactions are shown below in the chemical equations.

$$CaCO_3 \rightarrow CaO + CO_2$$

$$MgCO_3 \rightarrow MgO + CO_2$$

Lime production results in $CO_2$ emissions due to calcination reaction of limestone during production and these emissions are reported under 2.A.1 CRF category. Moreover, lime production is an energy intensive process. Heating up the kiln with its load to such a high temperature is extremely energy consuming. Most of the kilns in Turkey uses coal, petroleum coke, lignite as the primary energy source. The emissions due to combusting of these fuels to heat up the kilns are included in 1.A.2.f CRF category. The following table shows allocation of lime production emissions in the CRF categories.

**Table 4.4 Allocation of lime production emissions**

| CRF category | Emission source |
|---|---|
| CRF 2.A.1 | Emissions from calcinations reactions in the kilns |
| CRF 1.A.2.f | Emissions from fuel consuming for the energy demand of the production plant. |

In Turkey lime is produced by a wide range of technology from old fashioned kilns to computer controlled plants. Most of the lime plants in Turkey are technologically new or modified to best available technologies. The old technology lime plants are minority in Turkey and their number is decreasing every year. Lime producers can be divided into two sub-categories, producers for the market and producers for their own internal consumption. Sugar refiners, soda ash manufacturers, and iron steel manufacturers produce lime for their own use. Sugar refiners and soda ash producers however use the produced $CO_2$ in their process steps and $CO_2$ is absorbed. Therefore, lime production of the sugar refiners and soda ash producers do not contribute to the greenhouse gas inventory.

Almost all of the lime produced in Turkey is quick lime and dolomitic. There is also some minor amount of hydraulic lime production in Turkey. However, it is known to be negligible amount of production with respect to total lime production.

The figure 4.4 shows the trend at lime production and the related $CO_2$ emissions between 1990 and 2018. The lime produced in Turkey is mostly used in the manufacturing and construction sector. Emissions from lime production are increased by 17.5% between 1990 and 2018. It is seen in the graph, emissions are decreased remarkably in 1992, in 2000-2001 period, and in 2008-2009 period due to slow down of the construction sector and economic recessions. The emissions from lime production seems to be going to increase in the future since manufacturing and construction sectors grow overall and the demand for lime increases.

**Figure 4.4 $CO_2$ emissions from lime production, 1990-2018**

### Methodological Issues:

The formula below is used to calculate emission from lime production.

$$CO2\ emissions = (M_{ql} - M_{cl}) \times EF_{ql} + M_{dl} \times EF_{dl}$$

Where:
$CO_2$emissions = emissions of $CO_2$ from lime production, tonnes
Mql = Production of quick lime
Mcl = Amount of captive lime (non emissive quick lime production)
Mdl = Production of dolomitic lime
EFql = Emission factor for quick lime
EFdl = Emission factor for dolomitic lime

In sugar industry lime is produced for sugar refining. Both the quick lime and the $CO_2$ is used for precipitating the impurities in the sugar. In the Turkish inventory it is assumed that all the $CO_2$ produced in lime production for sugar refining is precipitating and no $CO_2$ is emitted. Also in the soda ash production with solvay process, lime is produced and the resulting $CO_2$ is used in the process as an intermediate product. It is assumed that all the $CO_2$ produced from limestone in the soda ash production process is captured and no $CO_2$ emitted. Therefore, the lime produced for sugar industry and the soda ash production industry is deducted from the national lime production data and the emissions are calculated accordingly.

Consistent with the use of the tier 1 method, Turkey does not make any corrections to estimated emissions to account for emissions from production of hydrated lime or lime kiln dust.

**Collection of activity data**

Quick lime (CaO) production data are collected from the Lime Producers Association (KİSAD). KİSAD gathers about 88% (by 2015) of all the lime production data either by asking to member production plants or searching for the activity reports of other producers. The remaining 12% is estimated by KİSAD using the lime import and export data and related activity data in the industry. In addition, sectoral lime consumption data is also taken from KİSAD and therefore the amount of captive lime (lime produced for sugar industry and soda ash production industry) is obtained. The dolomitic lime is mostly used in the steel production. The dolomitic lime consumption data were collected from steel plants and the sum is assumed to be the national dolomitic lime production data.

**Table 4.5 Lime production and $CO_2$ emissions, 1990-2018**

(kt)

| Year | Quick Lime Production | Quick Lime produced for synthetic soda ash production | Quick Lime produced for sugar industry | Dolomitic lime production | CO2 Emissions |
|---|---|---|---|---|---|
| 1990 | 4 000 | 233 | 182 | 47 | 2 249 |
| 1991 | 3 930 | 280 | 192 | 47 | 2 183 |
| 1992 | 2 775 | 286 | 199 | 51 | 1 454 |
| 1993 | 3 860 | 297 | 205 | 57 | 2 133 |
| 1994 | 4 168 | 298 | 157 | 61 | 2 394 |
| 1995 | 4 090 | 334 | 140 | 66 | 2 359 |
| 1996 | 3 575 | 350 | 205 | 67 | 1 961 |
| 1997 | 4 049 | 360 | 273 | 72 | 2 245 |
| 1998 | 3 789 | 427 | 340 | 71 | 1 997 |
| 1999 | 3 527 | 465 | 251 | 72 | 1 864 |
| 2000 | 3 241 | 473 | 272 | 72 | 1 645 |
| 2001 | 2 972 | 477 | 183 | 76 | 1 520 |
| 2002 | 3 150 | 485 | 237 | 83 | 1 620 |
| 2003 | 3 231 | 491 | 187 | 92 | 1 704 |
| 2004 | 3 380 | 497 | 204 | 103 | 1 819 |
| 2005 | 3 584 | 506 | 224 | 106 | 1 925 |
| 2006 | 3 735 | 536 | 224 | 118 | 2 083 |
| 2007 | 3 952 | 575 | 134 | 129 | 2 280 |
| 2008 | 3 385 | 578 | 125 | 135 | 1 920 |
| 2009 | 2 877 | 558 | 110 | 127 | 1 605 |
| 2010 | 3 225 | 703 | 195 | 147 | 1 711 |
| 2011 | 3 819 | 747 | 301 | 171 | 2 031 |
| 2012 | 4 621 | 666 | 356 | 180 | 2 615 |
| 2013 | 4 400 | 715 | 300 | 174 | 2 486 |
| 2014 | 4 443 | 704 | 315 | 171 | 2 507 |
| 2015 | 4 325 | 683 | 313 | 158 | 2 429 |
| 2016 | 4 695 | 713 | 328 | 167 | 2 660 |
| 2017 | 4 868 | 863 | 342 | 189 | 2 684 |
| 2018 | 4 984 | 871 | 300 | 188 | 2 642 |

### Choice of emission factor

Country specific emission factor is used for quick lime whereas default emission factor is used for dolomitic lime (0.77 tonnes $CO_2$ per tonne lime) from the 2006 IPCC Guidelines. For calculating the country specific emission factor of quick lime, factories are asked for their amount of production and the CaO content of their product in 2016. By averaging on weight basis, the country specific CaO content of quick lime is calculated. Due to the stable trend in CaO content, this study was not iterated for the latest inventory and the 2015 value was used for the 2016-2018 inventories. The table below shows the average CaO content of quicklime and corresponding EF for each year.

**Table 4.6 Quick lime emission factors, 1990-2018**

| Year | Turkey's total quick lime production (kt) | Total quick lime production of the plants reporting CaO content (kt) | CaO content (%) | County specific emission factor | Representative-ness (%) |
|---|---|---|---|---|---|
| 1990 | 4 000 | 281 | 78.6 | 0.617 | 7.0 |
| 1991 | 3 930 | 320 | 79.1 | 0.621 | 8.2 |
| 1992 | 2 775 | 348 | 78.7 | 0.618 | 12.5 |
| 1993 | 3 860 | 383 | 79.3 | 0.622 | 9.9 |
| 1994 | 4 168 | 400 | 80.5 | 0.632 | 9.6 |
| 1995 | 4 090 | 399 | 81.3 | 0.638 | 9.8 |
| 1996 | 3 575 | 410 | 80.6 | 0.632 | 11.5 |
| 1997 | 4 049 | 439 | 81.6 | 0.641 | 10.8 |
| 1998 | 3 789 | 439 | 81.9 | 0.643 | 11.6 |
| 1999 | 3 527 | 405 | 81.9 | 0.643 | 11.5 |
| 2000 | 3 241 | 415 | 81.1 | 0.637 | 12.8 |
| 2001 | 2 972 | 371 | 80.5 | 0.632 | 12.5 |
| 2002 | 3 150 | 333 | 81.6 | 0.641 | 10.6 |
| 2003 | 3 231 | 327 | 81.5 | 0.640 | 10.1 |
| 2004 | 3 380 | 431 | 82.7 | 0.649 | 12.7 |
| 2005 | 3 584 | 426 | 82.3 | 0.646 | 11.9 |
| 2006 | 3 735 | 1 252 | 85.3 | 0.670 | 33.5 |
| 2007 | 3 952 | 1 368 | 85.7 | 0.672 | 34.6 |
| 2008 | 3 385 | 1 337 | 86.2 | 0.677 | 39.5 |
| 2009 | 2 877 | 1 180 | 86.9 | 0.682 | 41.0 |
| 2010 | 3 225 | 1 533 | 87.5 | 0.687 | 47.5 |
| 2011 | 3 819 | 1 786 | 87.3 | 0.685 | 46.8 |
| 2012 | 4 621 | 1 901 | 87.6 | 0.688 | 41.1 |
| 2013 | 4 400 | 1 829 | 88.5 | 0.695 | 41.6 |
| 2014 | 4 443 | 1 883 | 88.4 | 0.694 | 42.4 |
| 2015 | 4 325 | 1 854 | 88.3 | 0.693 | 42.9 |
| 2016 | 4 695 | 1 854 | 88.3 | 0.693 | 42.9 |
| 2017 | 4 868 | 1 854 | 88.3 | 0.693 | 42.9 |
| 2018 | 4 984 | 1 854 | 88.3 | 0.693 | 42.9 |

Note that representativeness indicates that the amount of quick lime with known CaO content divided by the total lime production of Turkey for each year. Obviously for the recent years more lime plants can report their CaO content while for the earlier years most plants cannot due to data unavailability. Therefore, the representativeness country specific emission factor decreases as the years go back.

### Uncertainties and Time-Series Consistency:

There is uncertainty due to not collecting data from each of the production plant but estimating some amount of the production. In addition, there is uncertainty associated with assuming the dolomitic lime production is equal to the consumption of dolomitic lime in steel industry. Overall ±10% uncertainty for the activity data is estimated.

The uncertainty value of the EF is estimated to be ±6 % as there is uncertainty in assuming the average CaO in lime with Approach 1.

In this submission, uncertainty in $CO_2$ emissions from category 2.A.2 was quantified using the Monte Carlo simulation again. Combined uncertainty in $CO_2$ emissions in 2017 is estimated at -16.87% to +17.92%. Further information about Monte Carlo analysis of lime production can be seen in Uncertainty chapter (Annex 2).

### Source-Specific QA/QC and Verification:

Plant specific lime production data from KİSAD is compared with ILA (International Lime Association) Although ILA report is based on the sales, KİSAD data and ILA data are found to be consistent. ILA reports 4 500 kilotons of lime sales in Turkey while KİSAD reports 4 868 kilotons of lime production in Turkey in 2017. (https://www.internationallime.org/world-lime-production/)

In addition, Turkey's 8th five years' development plan released an annex special to building materials. One part of this report was allocated for the lime production in Turkey and it includes historical lime production data for the years 1994-1998 which are exactly the same with our lime production data for those years in the time series.

In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

### Recalculations:

No recalculation.

### Planned Improvement:

It is planned to obtain a country specific emission factor for dolomitic lime and emissions form lime production is sugar factories in next submissions.

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

#### Source Category Description:

A variety of raw materials are involved during glass production. Limestone, dolomite and soda ash are the carbonates that compose the majority of raw materials. These carbonates emit $CO_2$ when heated (calcined) during the glass production and it is reported under 2.A.3 CRF category. Glass makers also use a certain amount of recycled scrap glass (cullet). Cullet usage decreases the raw material consumption and hence it reduces the costs and $CO_2$ emissions. During glass production carbon based fuels are burnt in order to melt the glass batch and as a result of this $CO_2$ emissions, which are reported under 1.A.2.f CRF category, are emitted. Table below shows allocation of glass production emissions in the CRF categories.

**Table 4.7 Allocations of glass production emissions**

| CRF category | Emission source |
|---|---|
| CRF 2.A.3 | Emissions from calcination reactions during production |
| CRF 1.A.2.f | Emissions from fuel consuming for the energy demand of the production process. |

Turkish glass industry produces various type of glasses with different chemical and physical properties. Turkey's glass sector comprises the three main categories: container (household goods and bottles), float glass and fiber glass. The majority of the glass production is container and flat glass in all the time series.

Turkish glass industry has roots back to the establishment of Paşabahçe in 1935 with a production capacity of only 3 kt. Turkey glass industry production peaked 4.3Mt in 2017 and it was 3.9 Mt in 2016. Since the Turkish glass industry does not have an advantage in terms of raw material and energy costs compared to its European peers, capacity utilization rates of the industry are the key indicator of the competitive edge and profitability. The industry depicted a tremendous growth trend either through capacity additions or through new product initiations between 1990 (1.13 Mt molten glass produced) and 2017 (4.4 Mt molten glass produced), increasing 288%. By 2017, Turkey is Europe's second and the world's fifth biggest float glass producer.

The trend in $CO_2$ emissions from glass production is given in the Figure 4.5. The emissions are increasing in general due to increasing glass production in Turkey. The time series shows a considerable decrease in 2009 due to effects of global economic recession in that year.

**Figure 4.5 $CO_2$ emissions from glass production, 1990-2018**

### Methodological Issues:

Estimation is based on the T3 method described in the 2006 IPCC Guidelines. Specifically, the calculation based on accounting for the carbonate input to the glass melting furnace

$$CO_2\ Emissions = \sum_i (M_i \bullet EF_i \bullet F_i)$$

Where:
$CO_2$ Emissions = emissions of $CO_2$ from glass production, tonnes
$EF_i$ = emission factor for particular carbonate i,tonnes $CO_2$/tonne carbonate
$M_i$=weight or mass of the carbonate i consumed (mined), tones
Fi = fraction calcination achieved for the carbonate i, fraction

**Collection of activity data**

Turkey produces float glass, container glass (including household glassware) and fiberglass for insulation. Total glass production of Turkey is done by 5 companies. Activity data of molten glass production by glass type and carbonate input directly from the plant for all the years 1990-2017.

In the following table, total $CO_2$ emissions and glass production by type are given.

**Table 4.8 Molten glass production and $CO_2$ emissions by type of glass, 1990-2018**

(kt)

| Year | Total Glass Production | Float Glass | Container (households +bottles) | Fiberglass | $CO_2$ emission from glass |
|---|---|---|---|---|---|
| 1990 | 1 129 | 650 | 456 | 23 | 111 |
| 1991 | 1 113 | 669 | 427 | 17 | 111 |
| 1992 | 1 157 | 625 | 508 | 24 | 112 |
| 1993 | 1 163 | 606 | 533 | 24 | 110 |
| 1994 | 1 183 | 614 | 547 | 22 | 112 |
| 1995 | 1 290 | 625 | 643 | 22 | 120 |
| 1996 | 1 541 | 748 | 772 | 21 | 141 |
| 1997 | 1 789 | 782 | 978 | 29 | 171 |
| 1998 | 1 846 | 824 | 990 | 32 | 178 |
| 1999 | 1 681 | 771 | 878 | 32 | 166 |
| 2000 | 1 934 | 974 | 922 | 38 | 199 |
| 2001 | 1 843 | 880 | 919 | 44 | 224 |
| 2002 | 1 870 | 870 | 955 | 45 | 226 |
| 2003 | 2 069 | 991 | 1 016 | 62 | 262 |
| 2004 | 2 119 | 1 002 | 1 047 | 70 | 259 |
| 2005 | 2 175 | 1 016 | 1 085 | 74 | 280 |
| 2006 | 2 090 | 938 | 1 080 | 72 | 269 |
| 2007 | 2 427 | 1 141 | 1 213 | 73 | 292 |
| 2008 | 2 754 | 1 385 | 1 299 | 70 | 380 |
| 2009 | 2 174 | 1 075 | 1 048 | 51 | 299 |
| 2010 | 2 800 | 1 452 | 1 294 | 54 | 402 |
| 2011 | 3 169 | 1 746 | 1 348 | 75 | 464 |
| 2012 | 3 106 | 1 525 | 1 499 | 82 | 467 |
| 2013 | 3 186 | 1 624 | 1 485 | 77 | 476 |
| 2014 | 3 560 | 1 876 | 1 618 | 66 | 520 |
| 2015 | 3 444 | 1 661 | 1 718 | 65 | 526 |
| 2016 | 3 982 | 1 996 | 1 934 | 52 | 588 |
| 2017 | 4 375 | 2 305 | 2 023 | 48 | 686 |
| 2018 | 4 427 | 2 253 | 2 140 | 34 | 650 |

According to the figures in table above, glass production shows a steady increase for the years 2002-2008 after the economic recession years of 1999-2001 of Turkey (1 870 kt in 2002 and 2 754 kt in 2008). The production decreased in the year 2009 (2 174 kt) due to the global economic recession. Then it showed a general trend of growth till 2017 (4 375 kt). In 2018 the growth is continued and total glass production become 4 427 kt, and $CO_2$ emissions become 650 kt.

**Choice of emission factor**

$CO_2$ emissions are calculated using the 2006 IPCC Guidelines Volume 3default EFs for the carbonates (Table 2.1). The emission factors for each type of carbonate are given below.

**Table 4.9 EFs for carbonates, 1990-2018**

| Carbonate | EF (tonnes $CO_2$/tonne carbonates) |
|---|---|
| Sodium carbonate or soda ash | 0.41492 |
| Limestone | 0.43971 |
| Dolomite | 0.47732 |

### Uncertainties and Time-Series Consistency:

Due to emissions from glass production are estimated based on the carbonate input (Tier 3), the emission factor uncertainty is relatively low because the emission factor is based on a stoichiometric ratio. There may be some uncertainty associated with assuming that there is 100 percent calcination of the carbonate input (1%). Emission factor uncertainty is assumed as 3% while the emission factor for activity data is assumed %3 under the Tier 3 approach.

In this submission, uncertainty for $CO_2$ emissions from category 2.A.3 was quantified using the Monte Carlo simulation for the first time. The MC analysis resulted with (-9.63%,+9.82%) combined uncertainty. Detailed information is in Annex 2.

### Source-Specific QA/QC and Verification:

Data gathered from companies are compared reported data to the Ministry of Environment and Urbanization under the "Monitoring, Reporting and Verification" regulation. In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

### Recalculation:

No recalculation made in this sector.

### Planned Improvements:

No further improvements are planned at this time.

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

The category, other process uses of carbonates, is a key category. In this category, emissions from ceramics production, other uses of soda ash and non-metallurgical magnesia production and bricks and roof tile are reported. Between 1990 (619 kt $CO_2$ eq) and 2018 (3 356 kt $CO_2$eq) emissions have increased by over 642%, driven largely by the increase in $CO_2$ emissions from bricks production (1 279 kt $CO_2$ increase between 1990 and 2017).

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

#### Source Category Description:

Ceramics production is a source of $CO_2$ emissions since raw materials like limestone and magnesite are calcined during manufacturing. Moreover, ceramic production is an energy intensive process. Heating up the ceramics to such a high temperature for calcination is extremely energy consuming. Most of the ceramic manufacturers in Turkey use natural gas for this purpose. The emissions due to combusting of fuels to heat up the ceramics are included in 1.A.2.f CRF category. Table below shows allocation of cement production emissions in the CRF categories.

**Table 4.10 Allocations of ceramic production emissions**

| CRF category | Emission source |
|---|---|
| CRF 2.A.1 | Emissions from calcination reactions in the ceramic ovens |
| CRF 1.A.2.f | Emissions from fuel consuming for the energy demand of the production process |

The Turkish ceramics industry, which started production in an industrial sense, has become one of the largest ceramics manufacturers in the world in the last 50 years, which may be deemed quite short. It's becoming the third largest manufacturer in Europe in tiles with a production of 5 280 kilotons of tiles and again, the third largest in ceramic sanitary ware with production over 300 kilotons. Turkey is the world's sixth and Europe's third largest ceramic tile manufacturer.

Ceramics include the production of vitrified clay pipes, refractory products, expanded clay products, wall and floor tiles, table and ornamental ware, sanitary ware bricks and tile.

$CO_2$ emissions from ceramic production show an increasing trend for the years 1990-2018 overall. In 2018, ceramic production and the resulting $CO_2$ emissions increased by 11% with respect to 2017.

**Figure 4.6 $CO_2$ emissions, by raw materials type, from ceramics, 1990-2018**

### Methodological Issues:

The T2 method is used to estimate emissions from the ceramics industry. The method requires consumption data for each of the raw materials consumed, and multiplying by the respective emission factor for the carbonate to estimate $CO_2$ emissions.

$$CO_2\ emissions = \sum (M_i * EF_i)$$

Where:
$CO_2$Emissions = emissions of $CO_2$from other process uses of carbonates, tonnes
$M_i$= mass of limestone or dolomite respectively (consumption), tonnes.
$EF_i$= emission factor for carbonate calcination, tonnes $CO_2$/tonne carbonate

### Collection of activity data

Calcite, limestone, dolomite, magnesite and hydro-magnesite are consumed as raw materials in the ceramics industry. Production of ceramic tile and sanitary ware and carbonate consumption data (see the following table) are gathered from the Turkish Ceramics Federation for the time series 1990-2017. The amount of bricks and tile are gathered by Turkish Statistical Institute for the years 1990-1999 and 2005-2017. Data gaps for the years 2000-2004 is estimated. In this calculation following assumptions are made by using one of the plant data

1 $m^3$ brick= 600 kg,

1 brick = 4 kg,

1 tile = 3 kg,

$Kg_{clay} = 1.3 * kg_{bricks\ and\ tile}$

**Table 4.11 Raw material consumption and production, 1990-2018**

| | Raw Material (kt) | | | | | Product (kt) | | | Total Product(kt) |
|---|---|---|---|---|---|---|---|---|---|
| Year | Calcite | Limestone | Dolomite | Magnesite-hydro magnesite | Clay | Ceramic tile | Sanitary ware | Bricks and tile | |
| 1990 | 7 | 278 | 7 | 240 | 5 832 | 884 | 47 | 4 486 | 5 417 |
| 1991 | 9 | 282 | 9 | 243 | 6 102 | 1 020 | 56 | 4 694 | 5 769 |
| 1992 | 10 | 392 | 10 | 338 | 6 059 | 1 207 | 56 | 4 661 | 5 924 |
| 1993 | 12 | 444 | 12 | 382 | 7 342 | 1 428 | 59 | 5 648 | 7 135 |
| 1994 | 13 | 426 | 13 | 367 | 6 987 | 1 576 | 71 | 5 375 | 7 022 |
| 1995 | 15 | 544 | 15 | 469 | 6 712 | 1 819 | 78 | 5 163 | 7 060 |
| 1996 | 17 | 602 | 17 | 519 | 7 275 | 2 054 | 87 | 5 596 | 7 736 |
| 1997 | 21 | 701 | 21 | 605 | 7 182 | 2 514 | 102 | 5 524 | 8 140 |
| 1998 | 22 | 846 | 22 | 729 | 6 890 | 2 618 | 102 | 5 300 | 8 021 |
| 1999 | 21 | 832 | 21 | 717 | 6 474 | 2 550 | 106 | 4 980 | 7 636 |
| 2000 | 25 | 968 | 25 | 834 | 6 675 | 2 975 | 114 | 5 135 | 8 224 |
| 2001 | 22 | 836 | 22 | 720 | 6 876 | 2 559 | 109 | 5 289 | 7 957 |
| 2002 | 23 | 904 | 23 | 779 | 7 077 | 2 763 | 124 | 5 444 | 8 330 |
| 2003 | 27 | 1048 | 27 | 903 | 7 278 | 3 205 | 141 | 5 599 | 8 944 |
| 2004 | 31 | 1206 | 31 | 1 039 | 7 479 | 3 672 | 177 | 5 753 | 9 602 |
| 2005 | 37 | 1464 | 37 | 1 262 | 7 685 | 4 437 | 237 | 5 912 | 10 585 |
| 2006 | 38 | 1491 | 38 | 1 285 | 13 118 | 4 505 | 254 | 10 090 | 14 849 |
| 2007 | 37 | 1466 | 37 | 1 264 | 14 409 | 4 420 | 260 | 11 084 | 15 764 |
| 2008 | 32 | 1270 | 32 | 1 095 | 13 244 | 3 825 | 230 | 10 188 | 14 243 |
| 2009 | 29 | 1153 | 29 | 994 | 12 709 | 3 485 | 195 | 9 776 | 13 456 |
| 2010 | 35 | 1373 | 35 | 1 184 | 13 211 | 4 165 | 220 | 10 162 | 14 547 |
| 2011 | 37 | 1458 | 37 | 1 257 | 18 896 | 4 420 | 245 | 14 535 | 19 200 |
| 2012 | 40 | 1572 | 40 | 1 355 | 34 800 | 4 760 | 260 | 26 769 | 31 789 |
| 2013 | 47 | 1842 | 47 | 1 588 | 51 733 | 5 610 | 270 | 39 794 | 45 674 |
| 2014 | 43 | 1685 | 43 | 1 453 | 46 182 | 5 100 | 280 | 35 525 | 40 905 |
| 2015 | 46 | 1786 | 46 | 1 540 | 30 228 | 5 280 | 300 | 23 253 | 28 833 |
| 2016 | 47 | 1854 | 47 | 1 598 | 30 920 | 5 610 | 310 | 23 785 | 29 705 |
| 2017 | 49 | 1 912 | 49 | 1 675 | 47 388 | 5 755 | 352 | 36 452 | 42 559 |
| 2018 | 241 | 1 912 | 127 | 1 675 | 31 169 | 6 030 | 350 | 23 976 | 30 356 |

### Choice of emission factor

Default EFs provided in table 2.1 of the 2006 IPCC Guidelines are applied to the total raw material consumption for the entire time series to estimate emissions. The following table shows the default emission factors used in the calculations. EF for clay is calculated by using 7% CS carbon content of clay and default emission factor of calcite and limestone. To determine the average carbon content in clay, 11 plants were asked their raw material analysis result. This reveal that average carbon content in clay is around 7%.

**Table 4.12 Carbonate EFs for all years in the time series**

| Carbonate | EF (tonnes $CO_2$/ton carbonate) |
|---|---|
| Calcite and limestone | 0.43971 |
| Dolomite | 0.47732 |
| Magnesite | 0.52197 |
| Clay | 0.03077 |

Source: Table 2.1 of the 2006 IPCC Guidelines, Vol. 3

$CO_2$ emissions from each raw material are given in the table below and Figure 4.6.

**Table 4.13 $CO_2$ emissions from raw material consumption, 1990-2018 (kt)**

| Year | Calcite | Limestone | Dolomite | Magnesite | Clay | Total |
|---|---|---|---|---|---|---|
| 1990 | 3.3 | 122.2 | 3.6 | 125.1 | 179.5 | 433.7 |
| 1991 | 3.8 | 124.2 | 4.1 | 127.0 | 187.8 | 446.9 |
| 1992 | 4.4 | 172.4 | 4.8 | 176.4 | 186.5 | 544.6 |
| 1993 | 5.2 | 195.0 | 5.7 | 199.6 | 226.0 | 631.5 |
| 1994 | 5.8 | 187.1 | 6.3 | 191.5 | 215.1 | 605.8 |
| 1995 | 6.7 | 239.1 | 7.2 | 244.7 | 206.6 | 704.4 |
| 1996 | 7.5 | 264.6 | 8.1 | 270.8 | 223.9 | 774.9 |
| 1997 | 9.2 | 308.4 | 10.0 | 315.6 | 221.0 | 864.3 |
| 1998 | 9.6 | 372.1 | 10.4 | 380.7 | 212.1 | 984.8 |
| 1999 | 9.3 | 365.8 | 10.1 | 374.4 | 199.3 | 959.0 |
| 2000 | 10.9 | 425.4 | 11.8 | 435.4 | 205.5 | 1 088.9 |
| 2001 | 9.8 | 367.4 | 10.6 | 376.0 | 211.6 | 975.5 |
| 2002 | 10.2 | 397.5 | 11.0 | 406.8 | 217.8 | 1 043.3 |
| 2003 | 11.8 | 460.7 | 12.8 | 471.4 | 224.0 | 1 180.6 |
| 2004 | 13.5 | 530.1 | 14.7 | 542.5 | 230.2 | 1 331.0 |
| 2005 | 16.4 | 643.6 | 17.8 | 658.7 | 236.6 | 1 573.1 |
| 2006 | 16.7 | 655.4 | 18.2 | 670.7 | 403.8 | 1 764.9 |
| 2007 | 16.5 | 644.5 | 17.9 | 659.6 | 443.5 | 1 781.9 |
| 2008 | 14.3 | 558.4 | 15.5 | 571.5 | 407.7 | 1 567.3 |
| 2009 | 12.9 | 506.8 | 14.1 | 518.6 | 391.2 | 1 443.6 |
| 2010 | 15.4 | 603.9 | 16.7 | 618.0 | 406.6 | 1 660.7 |
| 2011 | 16.4 | 641.0 | 17.8 | 656.0 | 581.6 | 1 912.8 |
| 2012 | 17.7 | 691.3 | 19.2 | 707.5 | 1 071.1 | 2 506.8 |
| 2013 | 20.7 | 809.8 | 22.5 | 828.7 | 1 592.3 | 3 273.9 |
| 2014 | 18.9 | 740.9 | 20.5 | 758.2 | 1 421.5 | 2 960.1 |
| 2015 | 20.1 | 785.4 | 21.8 | 803.7 | 930.4 | 2 561.3 |
| 2016 | 20.8 | 815.3 | 22.6 | 834.3 | 951.7 | 2 644.7 |
| 2017 | 21.5 | 840.7 | 23.3 | 874.3 | 1 458.6 | 3 218.5 |
| 2018 | 106.1 | 840.7 | 60.6 | 874.3 | 959.4 | 2 841.1 |

### Uncertainties and Time-Series Consistency:

As the EF is the stoichiometric ratio reflecting the amount of $CO_2$ released upon calcination of the carbonate, the EF uncertainty in this category is relatively low. There is some uncertainty associated with assuming a fractional purity of limestone and dolomite in cases where only carbonate rock data are available (±1-5%).

AD uncertainties are greater than the uncertainties associated with EFs. Although there is a significant amount of roof tiles and bricks production in Turkey, unfortunately there is no verified activity data for this type of production. Only ceramic tiles and sanitary ware productions were taken into account. Therefore, for this category AD uncertainty is considered as 30% while the EF uncertainty is considered 2% which is in line with the 2006 IPCC Guidelines, Volume 3 (page 2.39).

Category 2.A.4.a employed a Monte Carlo uncertainty analysis which causes a combined uncertainty range (-19.24%,+20.79%) for $CO_2$ emissions in 2020 submission. Detailed explanation of Approach 2 method is in Uncertainty part of this inventory report (Annex 2).

### Source-Specific QA/QC and Verification:

Ceramics production data for both the ceramic tiles and sanitary-ware are compared to the Turkish construction sector report 2015. Both data are confirmed. In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

### Recalculations

There is no recalculation in this submission.

### Planned Improvements

There are no planned improvements in this sector.

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

#### Source Category Description:

In this category, emissions from soda ash consumption are considered. $CO_2$emissions from soda ash used in glass manufacturing industry are included in Glass Production. There are no other uses of soda ash included elsewhere in the Turkish Inventory.

Since soda ash is an important intermediate product primarily for the glass industry and detergent industry and it is used in many other industries. Soda ash apparent consumption increased dramatically between 1990 (314 901 tonnes) and 2018 (1 180 054 tonnes) as the Turkish industry grew. During the 2001 and 2008 economic recessions, soda ash consumption decreased remarkably. Since 2009 consumption has increased dramatically, driven by the growth of the glass industry in particular and the growth of Turkish industry in general. In 2018 the GHG release due to the apparent consumption of soda ash is 191 kilotons of $CO_2$.

**Figure 4.7 $CO_2$ emissions from other use of soda ash, 1990-2018**

#### Methodological Issues:

Turkey does not collect annual statistics on soda ash consumption by industry; instead the apparent consumption of soda ash is calculated by adding imports data to production data and then subtracting exports and the usage in the glass sector. In this methodology it is assumed that all of the apparent consumption of soda ash is emissive.

**Collection of activity data**

Apparent consumption is calculated by the following formula.

$$Total\ Consumption\ = Soda\ ash\ production + Imports - Exports$$

$$Apparent\ Consumption\ = Total\ Consumption - Use\ in\ Glass\ Industry$$

Total production values are gathered from the two soda ash producer plants while foreign trade statistics are provided by TurkStat. The data for the amount of soda ash used in the glass sector is estimated from the glass production data which was obtained from Union of Chambers and Commodity Exchanges of Turkey (TOBB) and Şişecam Company.

**Choice of emission factor**

The default EF (0.41492 tonnes $CO_2$ /tonnes product) taken from Table 2.1 of the 2006 IPCC Guidelines, Volume 3, Chapter 2 is applied for the full time series.

Total consumption, use in glass industry, apparent consumption and $CO_2$ emissions from soda ash consumption are given in the following table.

**Table 4.14 Activity data for the other use of soda ash and $CO_2$ emissions, 1990-2018**

**(kt)**

| Year | Total Consumption in Turkey | Use in Glass Industry | Apparent Consumption | $CO_2$ Emissions |
|---|---|---|---|---|
| 1990 | 315 | 116 | 199 | 83 |
| 1991 | 307 | 116 | 191 | 79 |
| 1992 | 317 | 116 | 201 | 83 |
| 1993 | 352 | 115 | 237 | 98 |
| 1994 | 336 | 117 | 218 | 91 |
| 1995 | 385 | 125 | 259 | 108 |
| 1996 | 469 | 148 | 321 | 133 |
| 1997 | 519 | 182 | 338 | 140 |
| 1998 | 578 | 192 | 387 | 160 |
| 1999 | 536 | 184 | 353 | 146 |
| 2000 | 601 | 221 | 380 | 158 |
| 2001 | 582 | 250 | 332 | 138 |
| 2002 | 668 | 248 | 420 | 174 |
| 2003 | 668 | 284 | 384 | 159 |
| 2004 | 713 | 280 | 433 | 180 |
| 2005 | 749 | 301 | 448 | 186 |
| 2006 | 747 | 291 | 456 | 189 |
| 2007 | 850 | 320 | 530 | 220 |
| 2008 | 891 | 419 | 472 | 196 |
| 2009 | 772 | 329 | 443 | 184 |
| 2010 | 807 | 441 | 366 | 152 |
| 2011 | 939 | 509 | 430 | 178 |
| 2012 | 918 | 510 | 409 | 170 |
| 2013 | 915 | 520 | 395 | 164 |
| 2014 | 944 | 561 | 383 | 159 |
| 2015 | 897 | 623 | 274 | 114 |
| 2016 | 1 017 | 637 | 380 | 158 |
| 2017 | 914 | 746 | 168 | 70 |
| 2018 | 1 180 | 719 | 461 | 191 |

**Uncertainties and Time-Series Consistency:**

AD uncertainty for this source is considered ±10% due to using national statistics and using a general apparent consumption calculation formula. Because a default EF based on stoichiometry is used for the emission calculation, uncertainty for the EF is defined as ±2%.

Moreover, Monte Carlo analysis has been carried out for the $CO_2$ emissions from other uses of soda ash production for the first time in this 2020 submission and it resulted with a range of -30.14% to +29.94% combined uncertainty. Further information about Monte Carlo analysis of other uses of soda ash production can be seen in Uncertainty chapter (Annex 2).

**Source-Specific QA/QC and Verification:**

There are only two plants in Turkey producing soda ash. The production data of these two plants and Turkish soda ash export data are compared together and the data are found to be consistent. In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

**Recalculations:**

There is no recalculation in this sector.

**Planned Improvements:**

No further improvement is planned at the moment.

### 4.2.4.3. Non metallurgical magnesia production (Category 2.A.4.c)

**Source Category Description:**

This source category should include emissions from magnesia (MgO) production that are not included elsewhere. Magnesite ($MgCO_3$) is one of the key inputs into the production of magnesia, and ultimately fused magnesia. There are three major categories of magnesia products: calcined magnesia, dead burned magnesia (periclase) and fused magnesia. Calcined magnesia is used in many agricultural and industrial applications (e.g., feed supplement to cattle, fertilizers, electrical insulations and flue gas desulphurisation). Deadburned magnesia is used predominantly for refractory applications, while fused magnesia is used in refractory and electrical insulating markets.

Magnesia (MgO) is produced by calcining magnesite ($MgCO_3$) which results in the release of $CO_2$ as shown in the chemical reaction below;

$$CaCO_3 \rightarrow CaO + CO_2$$

Depending on the calcination temperature, calcined magnesia or deadburned magnesia is produced. Deadburned magnesia requires higher temperatures and its purity is higher than calcined magnesia in terms of MgO. Fused magnesia is produced in the electrical arc furnaces at very high temperatures and it is the purest among all. The figure below shows the $CO_2$ emissions from total magnesia production between 1990 and 2018.

**Figure 4.8 $CO_2$ emissions from magnesia production, 1990-2018**

### Methodological Issues:

Turkey implements Tier 1 method. $CO_2$ emissions are calculated by using magnesia production (calcined production + deadburned magnesia) as AD and multiplied by the default IPCC EF. There is no significant amount of fused magnesia production in Turkey.

**Collection of Activity Data**

The magnesia production data are collected from the magnesia producers. There are seven plants that are producing magnesia in Turkey. Each of them were asked for their activity data by a questionnaire.

**Choice of Emission Factor**

The default IPCC EF (0.52197 tonnes $CO_2$ / tonne carbonate) taken from Table 2.1 of the 2006 IPCC Guidelines, Volume 3, Chapter 2, is applied for all the time series.

**Table 4.15 Magnesia production and $CO_2$ emissions, 1990-2018 (kt)**

| Year | Magnesia production | $CO_2$ |
|---|---|---|
| 1990 | 196.8 | 102.7 |
| 1991 | 188.3 | 98.3 |
| 1992 | 192.1 | 100.3 |
| 1993 | 184.4 | 96.3 |
| 1994 | 168.1 | 87.7 |
| 1995 | 242.5 | 126.6 |
| 1996 | 252.5 | 131.8 |
| 1997 | 268.8 | 140.3 |
| 1998 | 273.7 | 142.8 |
| 1999 | 238.3 | 124.4 |
| 2000 | 273.7 | 142.8 |
| 2001 | 303.8 | 158.6 |
| 2002 | 306.1 | 159.8 |
| 2003 | 311.0 | 162.3 |
| 2004 | 322.1 | 168.1 |
| 2005 | 316.6 | 165.3 |
| 2006 | 306.5 | 160.0 |
| 2007 | 338.5 | 176.7 |
| 2008 | 359.7 | 187.7 |
| 2009 | 292.8 | 152.8 |
| 2010 | 353.7 | 184.6 |
| 2011 | 353.2 | 184.4 |
| 2012 | 340.3 | 177.6 |
| 2013 | 426.8 | 222.8 |
| 2014 | 454.1 | 237.0 |
| 2015 | 441.4 | 230.4 |
| 2016 | 455.1 | 237.6 |
| 2017 | 658.1 | 343.5 |
| 2018 | 621.0 | 324.1 |

### Uncertainties and Time-Series Consistency:

AD is collected from the companies and all the 6 biggest producers are asked for their activity data. Therefore, the activity data uncertainty is 10%. Because the IPCC default EF is used for the emissions calculation, the uncertainty for the EF is defined as ±2%.

Additionally, an uncertainty analysis using the Monte Carlo technique was carried out to estimate emissions of $CO_2$ for 2.A.4.c category (Non metallurgical magnesia production) in 2020 inventory year. Combined uncertainty in $CO_2$ emissions in 2018 is estimated at the range of (-30.14%,+30.29%). For more detailed explanations please refer to Annex 2.

**Source-Specific QA/QC and Verification:**

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates and on proper use of notation keys in the CRF tables according to QA/QC plan. In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

**Recalculation:**

There is no recalculation in this sector.

**Planned improvement:**

No further improvement is planned at the moment.

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

In 2018, the chemical industry was responsible for 0.3% of the total carbon dioxide equivalent emissions from the industrial processes and product use sector. Between 1990 (1 629 kt $CO_2$ eq) and 2018 (3 093 kt $CO_2$ eq), total carbon equivalent emissions increased by 89.9%. The increase in emissions is driven exclusively by the increase in $CO_2$ emissions from ammonia production and $N_2O$ emissions from nitric acid production; emissions from all other sub-categories declined over the reporting period, 1990-2016.

Figure 4.9 depicts the share of $CO_2$ equivalent emissions from chemical industry. The $CO_2$eq. emissions from nitric acid production are (63%), followed by ammonia production and soda ash production (with 26.2% and 10.4% respectively). Carbide use and petrochemical production are much smaller contributors to emissions (0.4% and 0.1%, respectively). There is no production of adipic acid, caprolactam, glyoxal, glyoxylic acid, or titanium dioxide produced in Turkey, therefore emissions are reported as "NO" for these sub-categories.

**Figure 4.9 $CO_2$ emissions from chemical industry, 2018**

## 4.3.1. Ammonia production (Category 2.B.1)

### Source Category Description:

Ammonia is a major industrial chemical and the most important nitrogenous material produced. Ammonia gas is used directly as a fertilizer, in heat treating, paper pulping, nitric acid and nitrates manufacture, nitric acid ester and nitro compound manufacture, explosives of various types, and as a refrigerant. Amines, amides, and miscellaneous other organic compounds, such as urea, are made from ammonia.

Natural gas is used as the feedstock for ammonia production in Turkish production plants. $CO_2$ is formed during reforming of natural gas for obtaining hydrogen and then it is reacted with nitrogen to synthesis ammonia. The overall reforming reaction and ammonia synthesis reactions are given below.

Overall reforming reaction:

$$0.88CH_4 + 1.26Air + 1.24H_2O \rightarrow 0.88CO_2 + N_2 + 3H_2$$

Ammonia synthesis reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Ammonia production requires the combustion of fuels for the energy demand of the process. Besides being used as feedstock, natural gas is also used for meeting the energy requirement of the process. Both the emissions due to the ammonia production process and the fuel combustion for the energy demand are included in 2.B.1 CFR category. To avoid double counting, the total quantities of natural gas used in ammonia production is subtracted from the quantity reported under energy use in the energy sector. The following table shows the allocation of ammonia production emissions in the CRF categories.

**Table 4.16 Allocations of ammonia production emissions**

| CRF category | Emission source |
|---|---|
| CRF 2.B.1 | Emissions from ammonia production process and emissions from fuel consuming for the energy demand of the production plant. |

İGSAŞ is one of two ammonia plants in Turkey which started its operation in 1977. In 1993 a second ammonia plant, GEMLIK GUBRE, started its operation. İGSAŞ also produces urea by using $CO_2$ gas as feedstock. $CO_2$ is separated from the synthesis gas in the decarbonising step within the ammonia production process. Then, some of the $CO_2$ gas is used in the urea production process and the remaining gas is released to atmosphere. The chemical reaction that produces urea is:

$$2NH_3 + CO_2 \rightarrow NH_2COONH_4 \rightarrow CO(NH_2)_2 + H_2O$$

The figure 4.10 shows the $CO_2$ emissions from ammonia production as well as the amount of $CO_2$ recovered.

Overall, between 1990 (425 kt $CO_2$ eq.) and 2018 (1 038 kt $CO_2$ eq.), emissions from ammonia production increased by 144.5%. There are large inter-annual changes in $CO_2$ emissions from ammonia production. Rapid increases in emissions can be seen shortly after periods of economic downturns.

**Figure 4.10 $CO_2$ emissions and removals from ammonia production, 1990-2018**

### Methodological Issues:

In Turkey there are two ammonia production plants and both use natural gas as feedstock. Tier 2 method is used in accordance with the 2006 IPCC Guidelines. As an initial step, the total fuel requirement (both as feedstock and as combusted fuel for energy demand) is estimated by determining the total quantity of ammonia produced and the fuel requirement per unit of output. In order to calculate $CO_2$ emissions; the total fuel requirement is multiplied by the country-specific carbon content and the carbon oxidation factor.

$$TFR = \sum_j (AP_j * FR_j)$$

where:
TFR= total natural gas requirement, GJ
$AP_j$ = ammonia production using natural gas in process type *j*, tonnes
$FR_j$ = fuel requirement per unit of output in process type *j*, GJ/tonne ammonia produced

$$E_{CO2} = \sum (TFR \bullet CCF \bullet COF \bullet 44/12) - R_{CO2}$$

where:
$E_{CO2}$ = emissions of $CO_2$, kg
TFR= total fuel requirement for natural gas, GJ

CCF= carbon content factor of natural gas, kg C/GJ
COF= carbon oxidation factor of natural gas, fraction
$R_{CO2}$ = $CO_2$ recovered for downstream use (urea production), kg

**Collection of activity data**

Ammonia production and fuel requirement data are obtained from producers on annual basis. There is a survey related to the ammonia production and this survey is sent to the two producer companies every year. The producers inform that ammonia production and natural gas consumption data are measured by on-line flow meters in the process whereas urea production data is calculated from the raw material consumption.

Due to the fact that there are only two ammonia producers in Turkey, activity data are confidential. Therefore, production data are given as 1990=100 and all years are reported relative to ammonia production in 1990.

The total amount of urea produced in ammonia plants is obtained from the survey which sent to ammonia production plants and it is included in the following table. The urea production data and the ammonia production data are given with respect to 1990=100 by years. Therefore, one can compare the urea production and the ammonia production by years. Turkey assumes 0.733 tonnes of $CO_2$ are required per tonnes of urea produced. This value is taken from the 2006 IPCC Guidelines.

In Turkey; due to economic factors, there was no ammonia production in 2007 and 2009 as shown in the table below. During these two years, ammonia was imported to meet domestic demand.

**Table 4.17 Ammonia production and $CO_2$ emissions, 1990-2018**

| Year | Ammonia Production (1990=100) | Urea Production (1990=100) | $CO_2$ Emission (kt) | $CO_2$ Removal (kt) | Net $CO_2$ Emission (kt) |
|---|---|---|---|---|---|
| 1990 | 100 | 100 | 915 | 491 | 425 |
| 1991 | 95 | 95 | 870 | 466 | 404 |
| 1992 | 91 | 91 | 831 | 445 | 385 |
| 1993 | 82 | 84 | 759 | 412 | 347 |
| 1994 | 73 | 73 | 631 | 359 | 272 |
| 1995 | 82 | 85 | 764 | 415 | 348 |
| 1996 | 76 | 77 | 703 | 377 | 326 |
| 1997 | 81 | 84 | 746 | 413 | 334 |
| 1998 | 66 | 69 | 633 | 337 | 296 |
| 1999 | 22 | 22 | 213 | 110 | 103 |
| 2000 | 15 | 14 | 158 | 70 | 88 |
| 2001 | 18 | 17 | 167 | 85 | 82 |
| 2002 | 82 | 80 | 749 | 394 | 355 |
| 2003 | 79 | 73 | 714 | 358 | 356 |
| 2004 | 90 | 74 | 818 | 361 | 456 |
| 2005 | 104 | 77 | 945 | 378 | 567 |
| 2006 | 25 | 22 | 225 | 108 | 117 |
| 2007 | 0 | 0 | 0 | 0 | 0 |
| 2008 | 27 | 22 | 257 | 106 | 151 |
| 2009 | 0 | 0 | 0 | 0 | 0 |
| 2010 | 21 | 17 | 201 | 82 | 119 |
| 2011 | 128 | 77 | 1 232 | 376 | 856 |
| 2012 | 143 | 65 | 1 360 | 321 | 1039 |
| 2013 | 97 | 54 | 908 | 263 | 645 |
| 2014 | 107 | 35 | 993 | 174 | 818 |
| 2015 | 157 | 64 | 1 503 | 314 | 1190 |
| 2016 | 105 | 44 | 1 002 | 215 | 787 |
| 2017 | 82 | 65 | 844 | 319 | 525 |
| 2018 | 150 | 74 | 1 402 | 364 | 1 038 |

**Choice of emission factor**

Turkey applies the carbon content of natural gas and an oxidation factor to the total fuel requirement to estimate emissions. The carbon content of the natural gas is provided by BOTAŞ (Petroleum Pipeline Corporation) and it is the same as that used in the energy sector.

### Uncertainties and Time-Series Consistency:

Because a country specific EF is used for the calculation of emissions from ammonia production, uncertainty is taken as ±5%.

Consistent with the 2006 IPCC Guidelines, due to the use of plant specific activity data, the uncertainty value for AD is considered as ±2%.

In this submission, uncertainty for $CO_2$ emissions from category 2.B.1 was quantified using the Monte Carlo simulation for the first time. The MC analysis resulted with (-7.46%,+7.54%) combined uncertainty. Detailed information is in Annex 2.

**Source-Specific QA/QC and Verification:**

There are two ammonia producers in the Turkish market. Both producers utilize natural gas to produce ammonia and both use the same process. Hence their implied emission factors are comparable. When compared they are found consistent. Furthermore, total ammonia production data of Turkey obtained from the producers is compared with data from PRODCOM and these two datasets are in the ±3% range since 2010. In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

**Recalculation:**

No recalculation made in this sector.

**Planned Improvement**

No further improvements are planned at this time.

## 4.3.2. Nitric acid production (Category 2.B.2)

**Source Category Description:**

Nitrous oxide ($N_2O$) is emitted during the production of nitric acid which is a raw material mainly in the manufacturing of nitrogenous-based fertilizer. Nitric acid is also used in the production of explosives, for metal etching and in the processing of ferrous metals.

In Turkey; these are four nitric acid plants, IGSAS (older names Yıldız Entegre and Kütahya Gübre) is in operation since 1961, Toros Tarım since 1972, Gemlik Gübre since 2006 and BAGFAŞ since 2015. These are medium pressure combustion plants. Some of these plants indicate their use of a selective catalytic reduction system.

$N_2O$ emissions were relatively stable between 1990 (3.57 kt $N_2O$) and 2005 (2.45 kt $N_2O$). Emissions from nitric acid production is not stable between 2005 and 2009 as can be seen from the figure 4.11,

this is due to a new nitric acid plant starts production in 2006 but stops its production in the same year and restarts production again in 2009. Moreover, one of the nitric acid plants starts using an abatement technology in 2008 which decreases its emission factor. $N_2O$ emissions reach its top in 2018 (6.12 kilotons). In 2016 $N_2O$ emissions was 4.09 kt and it is much less than year 2014 due to production stop in one big capacity nitric acid plant.

**Figure 4.11 $N_2O$ emissions from nitric acid productions, 1990-2018**

### Methodological Issues:

$N_2O$ emissions from nitric acid production are not a key category in Turkey. $N_2O$ emissions are calculated using the T1 method in the 2006 IPCC Guidelines. Total nitric acid production is multiplied by an emission factor as shown below.

$$E_{N2O} = EF \times Nitric\ acid\ production$$

where:
$E_{N2O}$ = $N_2O$ emissions, kg
EF = $N_2O$ emission factor (default), kg $N_2O$/tonne nitric acid produced

### Collection of activity data

Nitric acid production data were obtained from plants. A questionnaire is sent to nitric acid production plants every year and the production data is filled by the operators. Production data are reported for 100% concentration $HNO_3$ and the quantities are determined by flow meters measuring the nitric acid production flow through the pipelines and a totalizer sums up to give the annular production data.

**Choice of emission factor**

There are four nitric acid production plants, İGSAŞ, Toros Tarım, Gemlik Gübre and BAGFAŞ. Emission factors are determined according to their usage of abatement technology and its efficiency. However, the emission factors for each plant and the total nitric acid production cannot be revealed due to confidentiality reasons. Total nitric acid production is given relative to 1990, in the table below.

**Table 4.18 Nitric acid production and $N_2O$ emissions, 1990-2018**

| Year | Nitric acid production (kt) | Total $N_2O$ emission (kt) |
|---|---|---|
| 1990 | C | 3.57 |
| 1991 | C | 2.85 |
| 1992 | C | 3.22 |
| 1993 | C | 3.15 |
| 1994 | C | 2.18 |
| 1995 | C | 3.37 |
| 1996 | C | 3.41 |
| 1997 | C | 3.49 |
| 1998 | C | 3.32 |
| 1999 | C | 3.10 |
| 2000 | C | 2.84 |
| 2001 | C | 2.47 |
| 2002 | C | 2.79 |
| 2003 | C | 2.53 |
| 2004 | C | 2.40 |
| 2005 | C | 2.45 |
| 2006 | C | 5.51 |
| 2007 | C | 3.62 |
| 2008 | C | 2.76 |
| 2009 | C | 4.50 |
| 2010 | C | 5.55 |
| 2011 | C | 5.82 |
| 2012 | C | 5.96 |
| 2013 | C | 5.99 |
| 2014 | C | 6.07 |
| 2015 | 861 | 4.87 |
| 2016 | 771 | 4.09 |
| 2017 | 829 | 4.24 |
| 2018 | 1 066 | 6.12 |

### Uncertainties and Time-Series Consistency:

The 2006 IPCC Guidelines recommended default uncertainty value of ± 20% is used for the EF, consistent with the value in Table 3.3 for medium pressure combustion plants.

Turkey applies the default IPCC uncertainty value for AD uncertainty of ± 2%, which is in line with the 2006 IPCC Guidelines Volume 3 (page 3.25).

Category 2.B.2 (Nitric acid production) employed a Monte Carlo uncertainty analysis which causes a combined uncertainty as ±20.59% for $N_2O$ emissions in 2020 submission. Detailed explanation of Approach 2 method is in Uncertainty part of this inventory report (Annex 2).

**Source-Specific QA/QC and Verification:**

Plant specific nitric acid production data, which are collected from the plants by an annual questionnaire for this inventory calculations, are compared with TurkStat PRODCOM -Turkish national industrial production statistics- and found consistent. According to the monitoring, reporting and verifying regulation, nitric acid plants are obliged to report their emissions to the Ministry of Environment and Urbanization by measuring their emissions with $N_2O$ gas monitoring device. Calculated and reported emissions are compared first time in this submission. In this submission emission calculation was done by using two different calculation tools by two people. One is typically Excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

**Recalculation:**

There is no recalculation in this sector.

**Planned Improvements:**

There is no further planned improvement

### 4.3.3. Adipic acid production (Category 2.B.3)

There is no adipic acid production in Turkey during the period 1990-2015.

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

There is no caprolactam, glyoxal and glyoxylic acid production in Turkey during the period 1990-2016.

## 4.3.5. Carbide production (Category 2.B.5)

### Source Category Description:

The production of carbide can result in emissions of $CO_2$, $CH_4$, CO and $SO_2$. Silicon carbide is a significant artificial abrasive. It is produced from silica sand or quartz and petroleum coke. Calcium carbide is used in the production of acetylene and as a reductant in electric arc furnaces. The acetylene is used for welding applications. Therefore, use of acetylene also results in emissions and it is accounted in the IPPU.

Calcium carbide is produced by the reaction of metallurgical coke and lime under electric arc according to the reaction given below.

$$CaO + 3C \rightarrow CaC_2 + CO \ (+ \tfrac{1}{2} O_2 \rightarrow CO_2)$$

Calcium carbide is used either as a reductant in the steel making process or the feedstock for acetylene production in Turkey. Afterwards acetylene is used as fuel in the welding applications. The combustion of acetylene in welding applications give emissions according to the reaction given below and it is accounted in IPPU sector.

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2 \ (+ 2.5O_2 \rightarrow 2CO_2 + H_2O)$$

In Turkey there is no silicon carbide production. Calcium carbide has been produced in Turkey till 2015. The amount of coke used is deducted from the Energy part of the NIR to avoid double count.

$CO_2$ emissions from calcium carbide production and usage of carbide in acetylene was 59 kt $CO_2$ in 1990. Year by year carbide production decreased and in 2015 the carbide production and usage of carbide in acetylene production emissions was 12.1 kt $CO_2$. Finally, in 2016 the production line of carbide was closed due to economic reasons. And use of carbide in acetylene continued and resulted 6.2 kt $CO_2$ emissions in 2018.

**Figure 4.12 $CO_2$ emissions due to carbide production, 1990-2018**

### Methodological Issues:

Carbide production is not a key category in Turkey. Calcium carbide was produced in Turkey by a single plant till 2015 and then the production line was closed. The calculation of emissions is based on plant-specific data.

$$E_{CO2} = AD * EF$$

Where:
$ECO_2$= emissions of carbon dioxide
AD = activity data on carbide production
EF = $CO_2$emission factor.

The use of calcium carbide also leads to the emissions and it is calculated by the tier 1 methodology suggested in the guideline. The amount calcium carbide used is multiplied with the proper emission factor suggested in the guideline.

### Collection of activity data

The calcium carbide production data is directly obtained from the producer on an annual basis by a questionnaire. Both amount of carbide produced and amount of raw material used as metallurgical coke data are obtained. However, emissions are calculated by using the carbide production data.

Confidential production data are provided relative to 1990, along with $CO_2$ emissions from calcium carbide production as can be seen in the table below.

**Table 4.19 Calcium carbide production and $CO_2$ emissions, 1990-2018**

| Years | Calcium Carpide Production (1990=100) | Calcium carpide use (kt) | $CO_2$ Emissions from carbide production (kt) | $CO_2$ Emissions (kt) |
|---|---|---|---|---|
| 1990 | 100.0 | 15.9 | 41.5 | 59.0 |
| 1991 | 51.2 | 11.6 | 21.3 | 34.0 |
| 1992 | 65.3 | 17.0 | 27.1 | 45.8 |
| 1993 | 37.5 | 8.8 | 15.6 | 25.3 |
| 1994 | 46.3 | 17.8 | 19.2 | 38.7 |
| 1995 | 24.2 | 6.9 | 10.0 | 17.6 |
| 1996 | 40.6 | 14.2 | 16.8 | 32.4 |
| 1997 | 37.7 | 10.4 | 15.6 | 27.0 |
| 1998 | 56.3 | 17.6 | 23.3 | 42.7 |
| 1999 | 40.7 | 11.9 | 16.9 | 30.0 |
| 2000 | 43.3 | 13.6 | 18.0 | 32.9 |
| 2001 | 33.8 | 9.7 | 14.0 | 24.7 |
| 2002 | 25.7 | 6.4 | 10.6 | 17.7 |
| 2003 | 34.3 | 10.7 | 14.2 | 26.0 |
| 2004 | 40.6 | 15.0 | 16.8 | 33.4 |
| 2005 | 27.1 | 10.8 | 11.2 | 23.1 |
| 2006 | 29.4 | 11.9 | 12.2 | 25.3 |
| 2007 | 50.5 | 16.7 | 20.9 | 39.3 |
| 2008 | 11.9 | 5.1 | 4.9 | 10.6 |
| 2009 | 29.4 | 13.0 | 12.2 | 26.5 |
| 2010 | 19.8 | 9.4 | 8.2 | 18.6 |
| 2011 | 28.0 | 10.7 | 11.6 | 23.4 |
| 2012 | 28.8 | 8.1 | 11.9 | 20.9 |
| 2013 | 27.4 | 9.4 | 11.4 | 21.7 |
| 2014 | 25.9 | 9.2 | 10.7 | 20.9 |
| 2015 | 13.9 | 5.7 | 5.8 | 12.1 |
| 2016 | 0 | 7.0 | 0.0 | 7.7 |
| 2017 | 0 | 6.9 | 0.0 | 7.6 |
| 2018 | 0 | 5.7 | 0.0 | 6.2 |

### Choice of emission factor

Due to confidentiality the emission factor of the carbide production cannot be revealed.

### Uncertainties and Time-Series Consistency:

The greatest contributor to the uncertainty is that the assumption made upon all of the carbide is used for producing acetylene gas. Depending on the expert judgment the uncertainty value of the EF is taken ±20% while the default uncertainty value of the activity data is taken as 5% consistent with the 2006 IPCC Guidelines. (Volume 3 Page 3.45).

In this year's submission combined uncertainty estimates of Carbide production (Category 2.B.5) are quantified using the Monte Carlo simulation also. Uncertainty in Category 2.B.5 $CO_2$ emissions in 2018 are estimated at -20.55% to +20.87% with Approach 2 method. For more details, please refer to the Uncertainty chapter at the end of the Inventory report in Annex 2.

### Source-Specific QA/QC and Verification:

Plant-specific production data are compared with national statistics data available from PRODCOM (Turkey's National Industrial Production Statistics). National statistics were available only for the 2009-2017. For the year 2014, the data are found to be different as much as 2% whereas in the other years there found to be no difference.

### Recalculation:

There is no recalculation for this year's inventory.

### Planned Improvements

No further improvements are planned at this time.

## 4.3.6. Titanium dioxide production (Category 2.B.6)

There is no titanium dioxide production in Turkey during the period 1990-2016.

## 4.3.7. Soda ash production (Category 2.B.7)

### Source Category Description:

Soda ash (sodium carbonate, $Na_2CO_3$) is a white crystalline solid that is used as a raw material in a large number of industries including glass manufacture, soap and detergents, pulp and paper production and water treatment. $CO_2$is emitted from the use of soda ash and these emissions are accounted for as a source under the relevant using industry as discussed in Volume 3, Chapter 2 in the 2006 IPCC

Guidelines. $CO_2$ is also emitted during production of soda ash, with the quantity emitted dependent on the industrial process used to manufacture soda ash.

Emissions of $CO_2$ from the production of soda ash vary substantially with the manufacturing process. Four different processes may be used commercially to produce soda ash. Three of these processes, monohydrate, sodium sesquicarbonate (trona) and direct carbonation, are referred to as natural processes. The fourth, the Solvay process, is classified as a synthetic process. Calcium carbonate (limestone) is used as a source of $CO_2$ in the Solvay process.

There are three soda ash plants in Turkey. One of these plants produces soda ash by utilizing trona and began operation in 2009, while the others produce synthetic soda ash (solvay process) and began operation in 1969. Third one started production in 2018.

In the Solvay process, sodium chloride brine, limestone, metallurgical coke and ammonia are the raw materials used in a series of reactions leading to the production of soda ash. Ammonia, however, is recycled and only a small amount is lost. From the series of reactions $CO_2$ is generated during calcination of limestone. The $CO_2$ generated is captured, compressed and directed to Solvay precipitating towers for consumption in a mixture of brine (aqueous NaCl) and ammonia. Although $CO_2$ is generated as a by-product, the $CO_2$ is recovered and recycled for use in the carbonation stage and in theory the process is neutral, i.e., $CO_2$ generation equals uptake.

Soda ash production by utilizing trona started in 2009 while emissions from soda ash production using the solvay process are not estimated due to the carbon neutral characteristic of the process. Therefore; for the years 1990-2008, emissive soda ash production is reported as not occurring. In the figure below you can see the trend of the $CO_2$ emissions from soda ash productions. In the year 2009 a small amount of $CO_2$ emitted due to plant was not working full capacity due to start up. In 2017 emissions from soda ash increased by 44.4% with respect to previous year and it was 208 kt of $CO_2$.

**Figure 4.13 $CO_2$ Emissions resulting from soda ash production 2009-2018**

### Methodological Issues:

The natural production process of soda ash results in $CO_2$ emissions. Turkey applies a Tier 1 method, for this non-key category, quantifying emissions based on the plant-specific activity data and default emission factor, and using the following formula:

$$E_{CO2} = AD * EF$$

Where:
$E_{CO2}$ = emissions of carbon dioxide in tonnes
AD = quantity of soda ash produced (from trona) in tonnes
EF = emission factor per unit of soda ash produced

**Collection of activity Data**

The amount of soda ash produced is the AD and it is directly taken from the plant. Data are acquired on a yearly basis and it is based on a questionnaire which is sent to the plant.

**Choice of emission Factor**

The EF is confidential. The EF was held constant over the time series.

The production trend and emissions can be seen from the table below.

**Table 4.20 Soda ash production and $CO_2$ emissions, 1990-2018**

| Year | Soda ash production by utilizing Trona (2009=100) | $CO_2$ Emissions (kt) |
|---|---|---|
| 1990-2008 | NO | NO |
| 2009 | 100 | 24 |
| 2010 | 451 | 110 |
| 2011 | 538 | 132 |
| 2012 | 535 | 131 |
| 2013 | 511 | 125 |
| 2014 | 554 | 135 |
| 2015 | 549 | 134 |
| 2016 | 588 | 144 |
| 2017 | 850 | 208 |
| 2018 | 1 905 | 466 |

### Uncertainties and Time-Series Consistency:

Turkey assumes that the uncertainty of the EF is 1% and the uncertainty of the AD is ±5% in consistent with the 2006 IPCC Guidelines (2006 IPCC Guidelines, Volume 3 page 3.55).

Moreover, Monte Carlo analysis has been carried out for the $CO_2$ emissions from soda ash production for 2020 submission and it resulted with -5.10% to +5.15% combined uncertainty. Further information about Monte Carlo analysis of soda ash production can be seen in Uncertainty chapter (Annex 2).

### Source-Specific QA/QC and Verification:

On the PRODCOM soda ash production data is available since 2009. PRODCOM data and plant specific data are compared and found consistent. Moreover, according to the 2006 IPCC Guidelines the emission from soda ash production can be calculated by either using the soda ash production data or using the trona consumption data. The emissions are calculated and reported using the soda ash production data. However, for quality control purpose the emissions is also calculated based on the trona consumption. The plant mines the trona by solving it underwater and then pumps it into the process. The amount of solution pumped and its purity is known by the plant. Therefore, the amount of trona utilized is calculated and reported by the plant. When the two methods are compared 12% difference is found for 2017. In this submission emission calculation was done by using two different calculation tools by two people. One is typically excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

### Recalculation:

There is no recalculation for this year's inventory.

### Planned Improvements

The solvay process is theoretically $CO_2$ neutral. However no process is 100% efficient in real life. Therefore, it is obvious that the solvay process plants cause some amount of $CO_2$ emissions under the IPPU category. The soda ash plant which is producing soda ash by solvay process in Turkey is obliged to prepare greenhouse gas emission report under the new regulations of the Ministry of Environment and Urbanization. This report will be accessed in the future and then it would be possible to make $CO_2$ emission estimation regarding to this plant.

## 4.3.8. Petrochemical and carbon black production (Category 2.B.8)

### Source Category Description:

The petrochemical industry uses fossil fuels (e.g., natural gas) or petroleum refinery products (e.g., naphtha) as feedstocks. Within the petrochemical industry and carbon black industry, primary fossil fuels (natural gas, petroleum, coal) are used for non-fuel purposes in the production of petrochemicals and carbon black. The use of these primary fossil fuels may involve combustion of part of the hydrocarbon content for heat raising and the production of secondary fuels (e.g., off gases).

Turkey reports $CO_2$ emissions from petrochemicals production. There is a single petrochemical producer in Turkey and the company name is PETKİM. Carbon black was produced by PETKİM till 2001, however it was at a different production site and this production site was closed in 2001.

During the production of petrochemicals various gases are generated. However PETKİM has a closed circuit that collects all the process gases, which includes greenhouses gases and combustible gases, and uses it as fuel. This fuel is named fuel gas and emissions due to the combustion of fuel gas is included in the energy sector. However, some of the fuel gas is combusted in the flare stacks and the emissions from the flare stacks are included in the IPPU category.

The figures below show the $CO_2$ emissions from flare stacks from the petrochemicals production at main production site of PETKIM between 1990 and 2017 and also carbon black production emissions at Kocaeli production site between 1990 and 2001.

**Table 4.21 $CO_2$ emissions from flaring in petrochemical sector, 1990-2018**

(kt)

| Year | $CO_2$ emissions from carbon black production | $CO_2$ emissions from flaring | Total $CO_2$ emissions in petrochemical industry |
|---|---|---|---|
| 1990 | 80.1 | 1.35 | 81.5 |
| 1991 | 84.4 | 1.35 | 85.8 |
| 1992 | 91.2 | 1.35 | 92.6 |
| 1993 | 91.4 | 1.35 | 92.7 |
| 1994 | 73.3 | 1.35 | 74.6 |
| 1995 | 104.7 | 1.35 | 106.1 |
| 1996 | 91.9 | 1.35 | 93.2 |
| 1997 | 102.3 | 1.35 | 103.7 |
| 1998 | 104.8 | 1.35 | 106.2 |
| 1999 | 69.2 | 1.35 | 70.6 |
| 2000 | 91.9 | 1.35 | 93.2 |
| 2001 | 70.9 | 1.35 | 72.2 |
| 2002 | NO | 1.35 | 1.35 |
| 2003 | NO | 1.35 | 1.35 |
| 2004 | NO | 1.35 | 1.35 |
| 2005 | NO | 1.35 | 1.35 |
| 2006 | NO | 1.35 | 1.35 |
| 2007 | NO | 1.35 | 1.35 |
| 2008 | NO | 1.35 | 1.35 |
| 2009 | NO | 1.35 | 1.35 |
| 2010 | NO | 1.35 | 1.35 |
| 2011 | NO | 1.35 | 1.35 |
| 2012 | NO | 1.35 | 1.35 |
| 2013 | NO | 1.35 | 1.35 |
| 2014 | NO | 1.35 | 1.35 |
| 2015 | NO | 1.35 | 1.35 |
| 2016 | NO | 1.32 | 1.32 |
| 2017 | NO | 1.35 | 1.35 |
| 2018 | NO | 1.19 | 1.19 |

Since PETKİM has a closed system for its stacks, all the methane emissions are assumed to be collected in the fuel gas. Hence it is covered in the energy sector.

### Methodological Issues:

$CO_2$ emissions are calculated by multiplying the amount of fuel gas burnt with the

$$E_{CO2} = M_{fuel\ gas} \times \text{Carbon content of fuel gas} \times 44/12$$

Where:
$E_{CO2}$= $CO_2$ emissions from production of petrochemical in tonnes
M fuel gas= Amount of fuel gas combusted as the flare gas in tonnes
44/12 = The molar weight ratio of carbondioxide to carbon

$CO_2$ emissions from carbon black production are calculated by Tier 1 methodology. The annual production amount is multiplied by the default $CO_2$ mission factor.

$$E_{CO2} = M_{carbon\ black} \times \text{Carbon Black } CO_2 \text{ EF}$$

Carbon black production also causes CH4 emissions. $CH_4$ emissions are calculated by Tier 1 methodology. The annual production amount is multiplied by the default $CH_4$ emission factor.

$$E_{CH4} = M_{carbon\ black} \times \text{Carbon Black } CH_4 \text{ EF}$$

**Collection of activity data**

In Turkey, there is a single producer of petrochemicals. The amount of fuel gas combusted in the flare stacks is asked to the producer by an annual questionnaire. The amount of fuel gas combusted is confidential since there is one single company producing petrochemicals.

**Choice of emission factor**

The fuel gas composition is asked to the producer. The volumetric gas composition data is gathered and it is used to calculate the carbon content of fuel gas. Since there is one single company in Turkey in the field of petrochemical production its fuel gas characteristic is confidential.

### Uncertainties and Time-Series Consistency:

As 2006 IPCC Guidelines recommended default uncertainty values is used as ±10% for EF and AD based on expert judgment and table 3.27 in the 2006 IPCC Guidelines, Volume 3.

In this submission, uncertainty in $CO_2$ emissions from category 2.B.8 was quantified using the Monte Carlo simulation for the first time. Combined uncertainty in $CO_2$ emissions in 2018 is estimated with a symmetrical normal distribution as ±14.29%. Further information about Monte Carlo analysis of petrochemical and carbon black production can be seen in Uncertainty chapter (Annex 2).

### Source-Specific QA/QC and Verification:

A site visit was done to the PETKİM in 2017 by the Turkstat's inventory compilers. During this site visit all the process flow charts were examined and discussed with PETKİM engineers in order to understand emission pathways and ensure all emissions are included and not double counted.

### Recalculation:

There is no recalculation in this sector.

### Planned Improvements

No further improvements are planned at this time.

## 4.3.9. Fluorochemical production (Category 2.B.9)

There is no fluorochemical production in Turkey during the period 1990-2017.

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

In 2018, the metal industry was responsible for 12 876 kt $CO_2$ eq., 19.7% of total emissions from the industrial processes and product use sector. The vast majority of emissions in the metal industry (97.8%) are from iron and steel production. Aluminum production was responsible for 181.5 kt $CO_2$ eq., 1.5% of metal emissions, and ferroalloys production 132 kt $CO_2$ eq., 1.1 % of metal emissions. Lead production was responsible for 9.0 kt $CO_2$ eq. contributed 0.07% of sector emissions (see Figure 4.14). Zinc was produced in Turkey till 1999, however zinc has not been produced since.

Between 1990 (7 601kt $CO_2$ eq.) and 2018 (11 903 kt $CO_2$ eq.), emissions from the metal industry increased by 56.6%, again driven in large part by the iron and steel industry, which nearly doubled its emissions during the time period, from 6 767 kt $CO_2$ eq. in 1990 to 11 903 kt $CO_2$ eq. in 2018. This increase in emissions was partially offset by the elimination of PFC emissions in aluminum production (PFC emissions were 625 kt $CO_2$ eq. in 1990 and it is 73 in 2018). There is no magnesium production in Turkey.

**Figure 4.14 Emissions from metal industry, 2018**

### 4.4.1. Iron and steel production (Category 2.C.1)

#### Source Category Description:

Iron and steel production processes result in $CO_2$ and $CH_4$ emissions to be covered under the IPPU category since carbon is used in the reduction process of iron oxides.

In Turkey currently there are three integrated iron and steel production plants. These facilities include sinter production units, blast furnaces for pig iron production, and basic oxygen furnaces. Besides these plants, there are electric arc furnace mills operating in Turkey. However, there is no direct reduced iron (DRI) production in Turkey. Emissions from the combustion of carbon containing fuels (i.e. natural gas, fuel oil) for energy purposes are included in the energy chapter of this report.

The integrated steel production plants demand iron ore. These plants meet their need from both domestic and foreign markets. In Turkey there is currently one plant producing pellet iron in order to supply the iron ore demand of the integrated steel plants.

Blast furnace units for pig iron production are the most emissive units among the iron and steel production processes. Iron oxide reduces into iron metal when reacted with carbon monoxide in the blast furnaces as shown in the reactions represented in equations below.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

$$3\ Fe_2O_3(s) + CO(g) \rightarrow 2\ Fe_3O_4(s) + CO_2(g)$$

$$Fe_3O_4(s) + CO(g) \rightarrow 3\ FeO(s) + CO_2(g)$$

Carbon monoxide is generated in the blast furnace from the carbon containing fuels (mainly coke) as can be seen in equation below. Coke provides the necessary carbon for both the reduction reactions as well the heat needed for melting the iron and the impurities. Besides, coke provides mechanical strength for the blast furnace burden.

$$2\ C(s) + O_2(g) \rightarrow 2\ CO(g)$$

Limestone is used in the blast furnaces for removing acidic impurities from the ore. When limestone is heated up to about 1500 °C it releases carbon dioxide and left as CaO by the reaction shown in equation below. Then CaO reacts with the acidic impurities and deposits at the bottom of the blast furnace.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Sinter production is also an emissive process within the iron and steel industry. Sinter plants in Turkey are within the integrated steel plants. Sintering is a heat treatment process that agglomerates iron ore fines and metallurgical wastes (i.e. collected dusts, sludge) into larger, stronger and porous particles

necessary for blast furnaces charging. The sintering process involves the heating of iron ore fines by burning coke fines to produce a semi-molten mass that solidifies into porous pieces of sinter. Coke gas is usually used to ignite the sinter blend. This process also involves reduction of some iron oxides into iron metal within the iron ore fines. Therefore, the same reactions given above for the reduction of iron oxides also works for the sintering process and causes $CO_2$ release. During the sintering process high temperatures are achieved and limestone is calcined and release $CO_2$ emissions.

Basic Oxygen Furnaces (BOF) are also a part of the integrated steel plants. BOF processes the product of the blast furnace which is molten iron to produce steel. The BOF process also emits $CO_2$. The process involves oxygen blowing into the molten iron and stirring it. The oxygen reacts with impurities to purify molten iron and also reacts with dissolved carbon leaving as $CO_2$. This process converts iron into steel.

Electric Arc Furnaces (EAF) is another process unit for producing steel. Unlike BOF, only scrap iron and steel is used in the EAF to produce steel. The scrap metal is melted using high voltage electric arcs. There would be iron oxides in the feed of the EAF. Therefore, these iron oxides should be reduced to iron with the same reactions given above that cause $CO_2$ emissions. Metallurgical coke, petroleum coke, graphite, anthracite, carbon granules and natural gas may be used as the carbon source. Besides that, oxygen is blown into the molten steel in order to remove excess carbon and other impurities and to improve steel quality. This process step also releases $CO_2$ emissions due to reaction of oxygen and carbon.

Iron and steel production is classified as heavy industry and it requires vast amount of energy. All of the integrated steel plants in Turkey recycle exhaust gases of the Blast Furnaces and Basic Oxygen Furnaces to meet up their energy requirement. These gases are collected and burnt in order to heat up the coke ovens, produce the high pressure steam requirement of the plant, pre heat the blast furnace air, produce electricity, heat up the rolls and for other small issues. Their emissions are covered in the energy sector of this report. Besides, integrated iron and steel production plants produce lime for their own consumption and lime production also causes $CO_2$ emission and it is covered in lime production part of IPPU. Table below shows allocation of iron and steel production emissions in the CRF categories.

**Table 4.22 Categorical allocation of emissions from iron and steel productions in Turkey**

| CRF category | Emission source |
|---|---|
| CRF 1.A.1.a | Public electricity and heat production |
| CRF 1.A.1.c | Emissions from fuels used in coking plants (coke oven gas and BF gases) |
| CRF 1.A.2.a | Emissions from fuels used in iron and steel plants' processes and power plants |
| CRF 2.A.2 | Process emissions from lime production in iron and steel plant |
| CRF 2.C.1 | Process emissions from iron and steel production |

In Turkey there are currently 3 integrated iron and steel plants and 28 electric arc furnaces mills operating. The table below presents 2.C.1 category $CO_2$ emissions between 1990 and 2017, and figure 4.15 shows the 2.C.1 category $CO_2$ emissions cumulatively revealing the emissions trend in the iron and steel production.

**Table 4.23 $CO_2$ emissions allocations in 2.C.1 category, 1990-2018 (kt)**

| Year | Emissions from Iron and Steel Production (integrated plants) | Emissions from Steel Production (EAF plants) | Emissions from sinter production | Emissions from pellet production | Total emissions in 2.C.1 CRF category |
|---|---|---|---|---|---|
| 1990 | 5 356 | 347 | 1 033 | 31 | 6 767 |
| 1991 | 5 835 | 349 | 946 | 30 | 7 160 |
| 1992 | 4 796 | 428 | 959 | 29 | 6 212 |
| 1993 | 4 736 | 510 | 1 000 | 30 | 6 276 |
| 1994 | 3 684 | 538 | 1 030 | 31 | 5 283 |
| 1995 | 3 579 | 595 | 988 | 26 | 5 188 |
| 1996 | 4 155 | 584 | 1 118 | 28 | 5 884 |
| 1997 | 3 966 | 624 | 1 167 | 22 | 5 779 |
| 1998 | 4 260 | 629 | 1 180 | 26 | 6 096 |
| 1999 | 3 930 | 642 | 1 149 | 26 | 5 747 |
| 2000 | 3 661 | 637 | 1 242 | 28 | 5 568 |
| 2001 | 3 800 | 679 | 1 165 | 26 | 5 670 |
| 2002 | 3 659 | 793 | 1 017 | 23 | 5 492 |
| 2003 | 3 947 | 878 | 1 094 | 23 | 5 942 |
| 2004 | 4 388 | 1 025 | 1 158 | 23 | 6 595 |
| 2005 | 4 313 | 1 039 | 1 358 | 34 | 6 744 |
| 2006 | 4 453 | 1 208 | 1 313 | 34 | 7 008 |
| 2007 | 4 789 | 1 355 | 1 364 | 39 | 7 547 |
| 2008 | 5 013 | 1 384 | 1 393 | 34 | 7 823 |
| 2009 | 5 288 | 1 242 | 1 351 | 41 | 7 922 |
| 2010 | 5 653 | 1 463 | 1 480 | 45 | 8 641 |
| 2011 | 6 218 | 1 769 | 1 642 | 45 | 9 674 |
| 2012 | 6 593 | 1 859 | 1 703 | 46 | 10 202 |
| 2013 | 6 658 | 1 731 | 1 867 | 44 | 10 301 |
| 2014 | 6 611 | 1 663 | 1 890 | 47 | 10 210 |
| 2015 | 6 981 | 1 434 | 1 985 | 46 | 10 446 |
| 2016 | 7 756 | 1 529 | 1 961 | 47 | 11 294 |
| 2017 | 7 544 | 1 817 | 2 150 | 45 | 11 557 |
| 2018 | 8 466 | 1 806 | 2 220 | 45 | 12 537 |

**Figure 4.15 $CO_2$ emissions allocations within the 2.C.1 CRF category, 1990-2018**

$CO_2$ emissions from iron and steel production in 2018 was 12.5 million tons and it increased by 80.6% since 1990. Beginning by the year 2000 steel production in Turkey have increased and Turkey became the world's 8th biggest crude steel producer reaching 37.5 million tons by 2018, it was 17th by 2000. In 2018 steel production was decreased by 0.6 % due to decrease in steel demand. Turkey's steel production capacity is over 50 million tons.

### Methodological Issues:

For the calculation of $CO_2$emissions from iron and steel production and sinter production in the integrated plants, the 2006 IPCC Tier 3 method is used.

The Tier 3 methodology equation for calculating $CO_2$ emissions from pig iron production and sinter production in the integrated plants is as follows:

$$E_{CO2} = \left[\sum_a (Q_a \times C_a) - \sum_b (Q_b \times C_b)\right] \times \frac{44}{12}$$

where;

$E_{CO2}$ = *Emissions from pig iron or sinter*
$a$ = *Input material a*
$b$ = *Output material b*
$Q_a$ = *Quantity of input material a*
$C_a$ = *Carbon content of material a*
$Q_b$ = *Quantity of output material b*
$C_b$ = *Carbon content of material b*
$44/12$ = *Stoichiometric ratio of $CO_2$ to C*

For the calculation of $CO_2$ emissions from pellet production, the 2006 IPCC Tier 1 method is used where total amount of pellet produced is multiplied with the emission factor.

$$E_{CO2,\ non-energy} = P \bullet EF_P$$

where;

$E_{CO2,\ non\text{-}energy}$ = emissions of $CO_2$ to be reported in IPPU Sector, tonnes

P = quantity of pellet produced nationally, tonnes

$EF_x$= emission factor, tonnes $CO_2$/tonne *x* produced

$CO_2$ emissions from steel production in EAFs are calculated by applying the Tier 2 method which is the carbon balance calculation on an aggregated national level. The equation is given below:

$$E_{CO2} = \left[\sum_a (Q_a \times C_a) - \sum_b (Q_b \times C_b)\right] \times \frac{44}{12}$$

The $CH_4$ emissions from sinter production are calculated using Tier 1 methodology. This is multiplication of the production data with the default emission factor as suggested in the 2006 IPCC Guidelines, the equations are shown below.

$$E_{CH4} = SI \times EF_{si}$$

In Turkey almost all of the by-product gases are collected and burnt for energy recovery. Therefore, it is assumed that no methane is emitted due to the pig iron production under 2C1 CRF category.

Figure 4.16 shows the allocations of the emissions from integrated iron and steel plants between Energy and IPPU sectors.

**Figure 4.16 Allocations of the emissions from integrated iron and steel plants**

## Collection of activity data

To estimate $CO_2$ and $CH_4$ emissions at integrated facilities, Turkey collects activity data via annual basis questionnaire from each of the three facilities. All the solid materials are weighted by scales whereas gaseous materials are measured by flowmeters and the annual values are calculated by a computer programmed totalizer.

Pellet is produced by a single company beside an iron mine in Turkey. The activity data is obtained from this company.

The quantity data of crude steel production and raw material consumption at electric arc furnaces is obtained from Turkish Steel Producers Association and General Directorate of Renewable Energy by an annual basis questionnaire.

Each of the integrated facility keeps an energy balance table where all the fuel consumptions and generations are recorded annually. These tables are the main data source for the fuel consumptions. The consumption of non-fuel materials, (e.g. limestone, dolomite), are asked by a questionnaire.

Sinter, pellet production and steel production by plant type are included in the table below.

**Table 4.24 Sinter, pellet and iron & steel production by plant type, 1990-2018 (kt)**

| Year | Total pellet production | Total sinter production | Steel production (BOF) | Steel production (EAF) | Total steel production |
|---|---|---|---|---|---|
| 1990 | 1 032 | 4 507 | 4 431 | 4 955 | 9 386 |
| 1991 | 1 000 | 4 240 | 4 360 | 4 991 | 9 351 |
| 1992 | 963 | 4 451 | 4 096 | 6 110 | 10 206 |
| 1993 | 1 004 | 4 462 | 4 150 | 7 283 | 11 433 |
| 1994 | 1 043 | 4 496 | 4 429 | 7 680 | 12 109 |
| 1995 | 855 | 4 285 | 4 695 | 8 501 | 13 196 |
| 1996 | 935 | 4 620 | 5 095 | 8 337 | 13 432 |
| 1997 | 744 | 4 866 | 5 450 | 8 918 | 14 368 |
| 1998 | 878 | 4 592 | 5 259 | 8 992 | 14 251 |
| 1999 | 852 | 4 335 | 5 271 | 9 171 | 14 442 |
| 2000 | 948 | 5 007 | 5 372 | 9 096 | 14 468 |
| 2001 | 857 | 4 750 | 5 400 | 9 703 | 15 104 |
| 2002 | 754 | 4 237 | 5 274 | 11 334 | 16 608 |
| 2003 | 776 | 4 639 | 5 903 | 12 546 | 18 449 |
| 2004 | 776 | 4 756 | 6 003 | 14 646 | 20 649 |
| 2005 | 1 120 | 5 355 | 6 254 | 14 847 | 21 101 |
| 2006 | 1 135 | 5 032 | 6 300 | 17 252 | 23 553 |
| 2007 | 1 292 | 5 243 | 6 512 | 19 362 | 25 874 |
| 2008 | 1 118 | 5 437 | 7 180 | 19 771 | 26 951 |
| 2009 | 1 371 | 5 131 | 7 717 | 17 741 | 25 458 |
| 2010 | 1 493 | 5 845 | 8 444 | 20 905 | 29 349 |
| 2011 | 1 495 | 6 361 | 9 023 | 25 275 | 34 298 |
| 2012 | 1 543 | 7 356 | 9 500 | 26 560 | 36 059 |
| 2013 | 1 480 | 7 617 | 10 111 | 24 723 | 34 834 |
| 2014 | 1 550 | 7 928 | 10 483 | 23 752 | 34 235 |
| 2015 | 1 547 | 8 567 | 11 215 | 20 482 | 31 697 |
| 2016 | 1 565 | 9 834 | 11 545 | 21 846 | 33 392 |
| 2017 | 1 501 | 9 342 | 11 795 | 25 963 | 37 758 |
| 2018 | 1 513 | 9 798 | 11 734 | 25 799 | 37 533 |

**Choice of emission factor**

To estimate $CO_2$ emissions from integrated facilities, Turkey collects any available plant-specific data on carbon content for integrated facilities and for the remaining materials the material-specific carbon content values from Table 4.3 of the 2006 IPCC Guidelines are applied for the entire time series. To determine carbon content, the facilities make laboratory analysis for the product iron and steel, for the process gases and for the coals used in the plant.

In order to estimate $CO_2$ emissions from EAF (Electric Arc Furnace), Turkey collects raw material consumption and steel production data. These input and output data are aggregated on national level and multiplied by the default carbon contents for each raw material. However, the raw material consumption data is not available before the year 2013. Hence the average implied emission factor found to be 0.0753 t $CO_2$ / t steel produced between 2013 and 2016, and this factor is applied for the previous years.

To estimate $CO_2$ emissions from pellet production, Turkey uses the default emission factor from the 2006 IPCC Guidelines (0.03 t $CO_2$/ t pellet) for the entire time series.

To estimate $CH_4$ emissions from sinter production, Turkey applies the default emission factor of 0.07 kg $CH_4$/ t sinter.

Default emission factors used in the calculations are provided in the table below.

**Table 4.25 Emission factors**

| Activity | $CO_2$ EF |
|---|---|
| Pellet production (used in all-time series) | 0.03 t/t pellet |
| EAF steel production (used between 1990-2012) | 0.0753 t/t steel |

| Activity | $CH_4$ EF |
|---|---|
| Sinter production (used in all-time series) | 0.07 kg/t sinter |

### Uncertainties and Time-Series Consistency:

Uncertainties for the activity data and the emission factors are estimated to be 10% and 25%, respectively. Because especially the activity data and the emission factors regarding the process gases (coke oven gas, blast furnace gas, oxygen steel furnace gas) are quite uncertain.

An uncertainty analysis using the Monte Carlo technique was carried out to estimate emissions of $CO_2$ and $CH_4$ for 2.C.1 category and also to other IPPU categories in 2020 inventory year. Combined uncertainty in $CO_2$ emissions in 2018 is estimated at the range of -29.05% to +29.32%, $CH_4$ emissions

is estimated as -13.04% to +11.59% in 2020 submission. Further information is given in Uncertainty part at the end of this inventory report (Annex 2).

### Source-Specific QA/QC and Verification:

There are three integrated iron and steel plants in Turkey and plant specific data are gathered from these plants. These integrated steel plants were built as public economic enterprises and all of them have been privatized until 2006. Due to significant improvements on data recording after privatization, the integrated steel plants data are reliable after 2006. The integrated steel plants have similar steel production techniques therefore their data can be compared to each other. Coke consumed/steel produced, coke breeze consumed/sinter produced ratios are compared to each other in order to identify potential inconsistencies and reporting errors. Moreover, Turkish inventory team had site visits and held meetings with experts from the field on integrated steel plants in 2016. Through the site visits and the meetings, process flow charts and data reporting issues were discussed in order to identify potential inconsistencies and reporting errors. Moreover, carbon mass balance is done over each of the three integrated plant by considering all carbon containing material input and output to the factories. So that the total emissions (both IPPU and Energy) of the three plants are calculated. Then it is compared with the summation of each emission categories (1.A.1.a, 1.A.1.c, 1.A.2.a, and 2.C.1) for iron and steel production. The comparison result is given in the below.

| |
|---|
| Emissions calculated by carbon mass balance over integrated plants= 20 524 kt |
| Summed up emissions for each CRF category for integrated plants = 21 408 kt |
| Percentage of equivalence = 96% |

The percentage of equivalence is 96% when the data of the three integrated plants are aggregated together, and on the plant basis the percentage of equivalence is at least 94%. The percentage of equivalence shows that the calculated emissions are reliable, but still it can be improved as discussed in the planned improvements.

In this submission emission calculation was done by using two different calculation tools by two people. One is typically excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

### Recalculations:

No recalculation made in this sector

**Planned Improvements:**

There is no further planned improvement in this sector

## 4.4.2. Ferroalloys production (Category 2.C.2)

**Source Category Description:**

Ferroalloy is the term used to describe concentrated alloys of iron and one or more metals such as silicon, manganese, chromium, molybdenum, vanadium and tungsten. Silicon metal production is usually included in the ferroalloy group because silicon metal production process is quite similar to the ferrosilicon process. These alloys are used for deoxidising and altering the material properties of steel. Ferroalloy facilities manufacture concentrated compounds that are delivered to steel production plants to be incorporated in alloy steels. Silicon metal is used in aluminum alloys, for production of electronics. Ferroalloy production involves a metallurgical reduction process that results in significant $CO_2$emissions. In Turkey there are currently two ferrochrome producer. These two producer are using electric arc furnaces to melt scrap iron and chromite ore in the pot. Some metallurgical coke is added in the pot to reduce chromite and produce ferrochrome.

Between 2011 and 2014 some amount of ferrosilicon manganese was also produced. However, plants are closed due to the high production costs.

In this category; emissions from ferrochromium and ferrosilicon manganese production are considered. Other types of ferroalloys are not produced in Turkey on industrial scale.

Although Turkey is rich in terms of chrome mines, ferrochrome production is relatively low. This is due to high prices of energy in Turkey. $CO_2$ emissions from ferroalloys production are driven by mainly ferrochrome production which is strongly depended on the energy prices. There was a decline in emissions between 2000 (47.6 kt $CO_2$) and 2004 (11 kt $CO_2$) owing to one of the ferrochromium producers was slowed down and finally out of operation during its privatization period. $CO_2$ emissions generally climbed until 2008 (92 kt $CO_2$) with economic growth before decreasing again in 2009 (59 kt $CO_2$) due to global economic recession and low demand on steel. There was then a steep increase between 2010 and 2013 (184 kt $CO_2$, an increase in emissions of 314%) due to two new investments on production of ferrosilica manganese. However ferrosilica manganese production plants were closed in 2012 and 2013 due to high energy costs. In 2018, $CO_2$ emissions from ferroalloy production was 170 kilotons.

**Figure 4.17 $CO_2$ emissions from ferroalloys production, 1990-2018**

### Methodological Issues:

Turkey reports $CO_2$ emissions from ferroalloys production following the IPCC Tier 1 approach, as shown in equation below. Ferroalloys production is not a key category in Turkey.

**$CO_2$ emissions from ferroalloys production**

$$E_{CO2} = \sum_i (MP_i * EF_i)$$

where;

$E_{CO2}$ = $CO_2$ emissions, tonnes
$MP_i$ = production of ferroalloy type i, tonnes
$EF_i$ = generic emission factor for ferroalloy type i, tonnes $CO_2$/ tonne specific ferroalloy product

**Collection of activity data**

Activity data are obtained from the two ferrochrome producers by a production survey on the yearly basis by TurkStat. Both the ferro-chromium production data and the reductant agent consumption data are gathered for all the time series. The coke used in the ferro chromium production is deducted from the total coke consumption of Turkey in the energy sector to avoid a double counting.

**Choice of emission factor**

Turkey applies the default $CO_2$ emission factors from the 2006 IPCC Guidelines, as shown in table below.

**Table 4.26 Ferroalloys emission factors**

| Ferro alloy | $CO_2$ EF (t $CO_2$/t product) |
|---|---|
| Ferrochromium | 1.3 |
| Siliconmanganese | 1.4 |

**Table 4.27 Ferroalloys production and emissions, 1990-2018**

| Years | Total ferroalloy production (1990=100) | $CO_2$ emission (kt) |
|---|---|---|
| 1990 | 100 | 62 |
| 1991 | 116 | 72 |
| 1992 | 107 | 66 |
| 1993 | 100 | 62 |
| 1994 | 98 | 61 |
| 1995 | 97 | 60 |
| 1996 | 109 | 67 |
| 1997 | 113 | 69 |
| 1998 | 113 | 70 |
| 1999 | 105 | 64 |
| 2000 | 77 | 48 |
| 2001 | 56 | 34 |
| 2002 | 24 | 15 |
| 2003 | 23 | 14 |
| 2004 | 18 | 11 |
| 2005 | 53 | 32 |
| 2006 | 121 | 74 |
| 2007 | 144 | 88 |
| 2008 | 149 | 92 |
| 2009 | 96 | 59 |
| 2010 | 138 | 85 |
| 2011 | 196 | 127 |
| 2012 | 184 | 153 |
| 2013 | 298 | 186 |
| 2014 | 205 | 126 |
| 2015 | 204 | 126 |
| 2016 | 219 | 135 |
| 2017 | 226 | 139 |
| 2018 | 276 | 170 |

### Source-Specific QA/QC and Verification:

In this inventory report the ferro alloy production data was gathered directly from the plants. Until last year report Turkstat's PRODCOM data, which is the yearly industrial production survey, have been used to calculate emissions. Therefore, last year the plant specific data and the PRODCOM data are compared. PRODCOM data was found to be between -4% and +8% interval compared with the totalized plant specific annual production data since 2005. In this submission emission calculation was done by using

two different calculation tools by two people. One is typically excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

There are two ferro chrome producers in Turkey. Both of them supply ferro alloy production and coke consumption data. The production and consumption ratios of the two producers are compared and found consistent.

**Uncertainties and Time-Series Consistency:**

Since the calculations are based on default Tier 1EFs and company derived production data, uncertainty values of EF are considered 25% and AD are 5% as recommended in Table 4.9 of 2006 IPCC Guidelines. Moreover, Monte Carlo analysis has been carried out for the $CO_2$ emissions from other uses of ferroalloys production for the first time in this 2020 submission and it resulted with a range of -25.15% to +25.52% combined uncertainty with means of recommended Approach 1 uncertainties. Further information about Monte Carlo analysis of other uses of ferroalloys production can be seen in Uncertainty chapter (Annex 2).

**Recalculation:**

There is no recalculation in this sector.

**Planned Improvements:**

No further improvements are planned at this time.

### 4.4.3. Aluminum production (Category 2.C.3)

**Source Category Description:**

Turkey estimates $CO_2$ and PFCs ($CF_4$ and $C_2F_6$) emissions from primary aluminum production. Primary aluminum is aluminum tapped from electrolytic cells or pots during the electrolytic reduction of metallurgical alumina (aluminum oxide). It thus excludes alloying additives and recycled aluminum.

Primary aluminum is molten or liquid metal tapped from the pots and that is weighed before transfer to a holding furnace or before further processing.

Eti Aluminum is Turkey's only producer of primary aluminum and it is the country's only fully integrated producer which takes in untreated ore downstream and then has the capacity to fulfill every process

requirement to the finished product. The company has its own bauxite ore mines located just 20 kilometers away from the factory and this is the starting point of its operations.

Eti Aluminyum's Seydişehir Aluminum Plant, located in the Central Anatolia region of Turkey, is an integrated primary aluminum production plant. From here the company is able to convert aluminum ore into metallic aluminum by first processing the ore and then shaping it through the use of casting, rolling and extrusion systems.

The integrated production process itself consists of five main production phases. These are bauxite mining, alumina production, liquid aluminum production, the alloying and casting of the liquid aluminum, and the last but by no means least, the production of semi and/or end products through the use of the aforementioned casting, rolling and extrusion processes.

Most carbon dioxide emissions result from the electrolysis reaction of the carbon anode with alumina ($Al_2O_3$).The consumption of prebaked carbon anodes and Soderberg paste is the principal source of process related carbon dioxide emissions from primary aluminium production. PFCs are formed during a phenomenon known as the 'anode effect' during liquid aluminum production via electrolysis. Eti Aluminium used Soderberg cells till the modernization of the aluminium production plant in 2015. In 2015 all of the Soderberg cells were replaced with the prebaked cells.

The $CO_2$ emissions from aluminum productions is shown in figure 4.18. Overall between 1990 (99 kt $CO_2$ eq) and 2018 (107 kt $CO_2$ eq.) emissions have increased by 8.3%. This is due to increasing aluminum production of Turkey. In 1993 aluminum production decreased remarkably. This is because of the excessive world aluminum stocks prior to the world economic recession of 1994. $CO_2$ emissions remained generally stable until a similar trend was seen in 2008 (111.8 kt), 2009 (51.2 kt) and 2010 (96.4 kt) similarly because of the world economic recession in 2008. In 2018, $CO_2$ emissions decreased 1% with respect to 2017 due to the decreasing aluminum production of Turkey.

**Figure 4.18 $CO_2$ emissions from aluminum production, 1990-2018**

$CF_4$ and $C_2F_6$ emissions are reported in the Table 4.37. Fluctuations in the trend are due to Anode Effect parameter changes as well as primary aluminum production trend.

From the year 2006, PFCs emissions from the aluminum production plant are estimated using T3 methodology.

Eti Aluminum have communicated that after privatization in 2005, there has been great savings in energy consumption in 2006, at the same time there has been a decreasing trend in the number of anode effects. As it can be seen from the table below, reductions in PFCs emissions have occurred after 2006.

### Methodological Issues:

Aluminum is a key category by the trend analysis due to the cessation of PFC emissions in the industry. $CO_2$ emissions from primary aluminum production are calculated by the T3 method for the entire time series. Eti Aluminum, the only primary aluminum producer in Turkey, switched its production process in the mid of 2015. The company is now using Prebaked smelters. Before that Søderberg process was used to produce aluminum. For 1990-2014 $CO_2$ emissions come from only Søderberg cells. However, in 2015 Søderberg cells were switched to Prebaked cells. In 2016 $CO_2$ emissions come from only Prebaked cells.

**Formula for $CO_2$ emissions from Soderberg cells**

$$E_{CO2} = \left(PC \times MP - \frac{CSM \times MP}{1000} - \frac{BC}{100} \times PC \times MP \times \frac{S_p + Ash_p + H_p}{100} - \frac{100 - BC}{100} \times PC \times MP \times \frac{S_c + Ash_c}{100} - MP \times CD\right) \times \frac{44}{12}$$

where;

$E_{CO2}$ = $CO_2$ emissions from paste consumption, tonnes $CO_2$
MP = total metal production, tonnes Al
PC = paste consumption, tonnes/tonne Al
CSM = emissions of cyclohexane soluble matter, kg/tonne Al
BC = binder content in paste, wt %
Sp = sulphur content in pitch, wt %
Ashp = ash content in pitch, wt %
Hp = hydrogen content in pitch, wt %
Sc = sulphur content in calcined coke, wt %
Ashc = ash content in calcined coke, wt %
CD = carbon in skimmed dust from Søderberg cells, tonnes C/tonne Al
44/12 = $CO_2$molecular mass: carbon atomic mass ratio, dimensionless

**$CO_2$ emissions from Prebaked cells**

$$E_{CO_2} = NAC \times MP \times \frac{C_a}{100} \times \frac{44}{12}$$

where;

$E_{CO2}$ = $CO_2$ emissions from paste consumption, tonnes $CO_2$
MP = total metal production, tonnes Al
NAC = net prebaked anode consumption per tonne of aluminum, tonnes C / tonne Al
Ca = carbon content in baked anodes, wt%
44/12 = $CO_2$ molecular mass: carbon atomic mass ratio, dimensionless

**PFC emissions**

PFCs are formed during a phenomenon known as the 'anode effect'. PFCs emissions have been estimated from the primary aluminum production multiplied for the relative EF ($CF_4$, $C_2F_6$), following a T3 IPCC methodology.

In the following Table 4.28, $CF_4$ and $C_2F_6$ EF are reported.

**Table 4.28 $CF_4$ and $C_2F_6$ EF, 1990-2018**

| Year | $C_2F_6$s EFs (kg/t) | $CF_4$s EFs (kg/t) |
|---|---|---|
| 1990 | 0.0632 | 1.4348 |
| 1991 | 0.0852 | 1.9315 |
| 1992 | 0.0743 | 1.6835 |
| 1993 | 0.0748 | 1.6959 |
| 1994 | 0.0646 | 1.4642 |
| 1995 | 0.0536 | 1.2157 |
| 1996 | 0.0535 | 1.2131 |
| 1997 | 0.0524 | 1.2067 |
| 1998 | 0.0534 | 1.2120 |
| 1999 | 0.0533 | 1.2082 |
| 2000 | 0.0535 | 1.2129 |
| 2001 | 0.0534 | 1.2100 |
| 2002 | 0.0531 | 1.2026 |
| 2003 | 0.0525 | 1.1884 |
| 2004 | 0.0522 | 1.1840 |
| 2005 | 0.0519 | 1.1771 |
| 2006 | 0.0382 | 0.9764 |
| 2007 | 0.0504 | 1.1421 |
| 2008 | 0.0480 | 1.0883 |
| 2009 | 0.0481 | 1.0908 |
| 2010 | 0.0474 | 1.0758 |
| 2011 | 0.0474 | 1.0747 |
| 2012 | 0.0458 | 1.0379 |
| 2013 | 0.0468 | 1.0613 |
| 2014 | 0.0473 | 1.0733 |
| 2015 | 0.0699 | 0.0826 |
| 2016 | 0.0852 | 0.1007 |
| 2017 | 0.0463 | 0.0547 |
| 2018 | 0.0238 | 0.0281 |

Due to the process change in Eti Aluminum, the company has switched to the Prebake cells just in 2015 after using Søderberg process for long years. This technology change has leaded to changing the coefficient numbers and the difference between 2014-2015 has occurred because of this reason. Also PFC, C2F6 and CF4 emission factors are recalculated in Eti Aluminum Facility in 2015-2016, calculation made by using the current coefficients in the Greenhouse Gas Monitoring Reporting Communiqué.

**Collection of activity data**

To estimate $CO_2$ emissions, the parameters below are obtained from the single producer. The data are obtained from the producer company by an annual questionnaire. However, plant specific data can only be obtained for the years 2005-2015, and for 1990-2004 the default parameters are used as the

emission factors and national statistics are used as the production data. The paste consumption data for 1990-2004 is assumed to be constant and same with the 2005 data. Total aluminum production is given in table 4.29 below.

**Table 4.29 Aluminum production emissions, 1990-2018**

| Year | Aluminium Production (tonnes) | $CO_2$ emissions (kt) |
|---|---|---|
| 1990 | 54 970 | 99.2 |
| 1991 | 56 377 | 101.7 |
| 1992 | 54 136 | 97.7 |
| 1993 | 29 978 | 54.1 |
| 1994 | 61 161 | 110.3 |
| 1995 | 63 439 | 114.4 |
| 1996 | 60 006 | 108.2 |
| 1997 | 60 001 | 108.2 |
| 1998 | 64 002 | 115.5 |
| 1999 | 63 140 | 113.9 |
| 2000 | 62 501 | 112.7 |
| 2001 | 61 730 | 111.4 |
| 2002 | 61 501 | 110.9 |
| 2003 | 61 705 | 111.3 |
| 2004 | 61 803 | 111.5 |
| 2005 | 60 001 | 102.2 |
| 2006 | 60 006 | 108.0 |
| 2007 | 63 439 | 117.3 |
| 2008 | 61 161 | 111.8 |
| 2009 | 29 978 | 51.2 |
| 2010 | 54 136 | 96.4 |
| 2011 | 56 377 | 100.3 |
| 2012 | 43 635 | 76.4 |
| 2013 | 32 160 | 55.3 |
| 2014 | 30 016 | 54.9 |
| 2015 | 45 870 | 74.7 |
| 2016 | 78 807 | 117.3 |
| 2017 | 75 523 | 108.4 |
| 2018 | 73 291 | 107.3 |

### Choice of emission factor

Some of the $CO_2$ emission factors are provided by the facility while some are used as default values. In the tables below the emission factors used in the formula for Søderberg cells and Prebaked cells can be found.

**Table 4.30 Emission factors for aluminum production with Soderberg cells, 2005-2015**

| Emission factor | Type of data | Value |
|---|---|---|
| PC (Paste consumption) | Plant specific | Confidential |
| CSM (Emissions of cyclohexane soluble matter) | Default | 4 kg / tonne Al |
| BC (Binder content in paste) | Plant specific | Confidential |
| Sp (Sulphur content in pitch) | Plant specific | Confidential |
| Ashp (Ash content in pitch) | Plant specific | Confidential |
| Hp (Hydrogen content in pitch) | Default | 3.3 wt% |
| Cc (Carbon content in calcined coke) | Plant specific | Confidential |
| Ashc (Ash content is calcined coke) | Plant specific | Confidential |
| CD (Carbon in skimmed dust from Søderberg cells) | Plant specific | Confidential |

Note: For 1990-2004 PC value assumed to be constant and same with the 2005 data. All other parameters are default for the years 1990-2004

**Table 4.31 Emission factors for aluminum production with Prebaked cells, 2015-2018**

| Emission factor | Type of data | Value |
|---|---|---|
| NAC (Net Prebaked Anode Consumption) | Plant specific | Confidential |
| Ca (Carbon content in baked anodes) | Plant specific | Confidential |

Note that the company, Eti Aluminyum, switched to the Prebake cells just in 2015 after using Søderberg process for long years. The system is not fully developed yet. NAC value is not measured but it is estimated by the process engineers of the company. In the further years it will be measured.

For the calculation of PFCs emissions, the company yearly supply data for the following parameters, from 1990:

- Primary aluminum production (tonnes);
- Anode effect (minute/day);
- $CF_4$ Slope coefficient;
- $C_2F_6$ Slope coefficient;
- $CF_4EF$ (kg $CF_4$/tonnes aluminum);
- $C_2F_6EF$ (kg $C_2F_6$/tonnes aluminum).

In the following table, PFCs, CF4 and C2F6 emissions are reported.

**Table 4.32 PFCs, $CF_4$ and $C_2F_6$ emissions from primary aluminum production, 1990-2018**

(kt CO2 eq.)

| Year | PFCs | $CF_4$ | $C_2F_6$ |
|---|---|---|---|
| 1990 | 692 767 | 645 736 | 47 030 |
| 1991 | 854 541 | 796 527 | 58 013 |
| 1992 | 781 918 | 728 835 | 53 083 |
| 1993 | 786 584 | 733 184 | 53 400 |
| 1994 | 693 652 | 646 561 | 47 090 |
| 1995 | 592 881 | 552 631 | 40 249 |
| 1996 | 597 281 | 556 733 | 40 548 |
| 1997 | 593 326 | 553 046 | 40 279 |
| 1998 | 593 870 | 553 553 | 40 316 |
| 1999 | 591 067 | 550 940 | 40 126 |
| 2000 | 591 382 | 551 234 | 40 148 |
| 2001 | 592 202 | 551 998 | 40 203 |
| 2002 | 595 920 | 555 464 | 40 456 |
| 2003 | 595 330 | 554 914 | 40 416 |
| 2004 | 600 776 | 559 990 | 40 785 |
| 2005 | 559 966 | 521 950 | 38 015 |
| 2006 | 460 953 | 432 984 | 27 968 |
| 2007 | 574 440 | 535 432 | 39 007 |
| 2008 | 527 708 | 491 881 | 35 826 |
| 2009 | 259 256 | 241 656 | 17 600 |
| 2010 | 513 882 | 478 997 | 34 885 |
| 2011 | 480 349 | 447 744 | 32 605 |
| 2012 | 359 053 | 334 676 | 24 376 |
| 2013 | 270 582 | 252 212 | 18 369 |
| 2014 | 255 411 | 238 072 | 17 339 |
| 2015 | 159 033 | 122 766 | 36 267 |
| 2016 | 140 691 | 58 698 | 81 992 |
| 2017 | 73 214 | 30 545 | 42 699 |
| 2018 | 36 574 | 15 257 | 21 316 |

As shown in table, since EF values decreased by half in years between 2016-2018, as a result emission values of PFCs, CF4 and C2F6 are decreased by half in same period. In the same years, total production value has also decreased.

### Uncertainties and Time-Series Consistency:

For $CO_2$ emissions, the uncertainty values of the T2 method is considered ±5% for the EF and ±1% for AD, as recommended in 2006 IPCC Guidelines Volume 3 (page 4.56). AD are relatively low as there is very little uncertainty in the data on annual production of aluminum and information is provided directly from the single producer. The $CO_2$ emission factor is also low as the mechanisms leading to emissions are well known. On the other hand, for F-gases, uncertainty values of T3 are considered 5% for EF and 2% for AD as recommended in 2006 IPCC Guidelines Volume 3 (page 4.56).

Category 2.C.3 employed a Monte Carlo uncertainty analysis which causes a combined uncertainty range (-5.15%,+5.16%) for $CO_2$ emissions in 2020 submission. Detailed explanation of Approach 2 method is in Uncertainty part of this inventory report (Annex 2).

**Source-Specific QA/QC and Verification:**

Within the scope of the Turkish National Greenhouse Gas Emission Inventory Improvement Project, Turkey's only primary aluminum producer, Eti Alüminyum A.Ş., was visited on July 2017 and detailed information on production processes and data recording systems were obtained. The emission calculation methodology, the parameters used in the formulation and the data gathered were discussed with sector experts. The methodology, the parameters and the data were also approved by the sector experts.

Aggregated national implied emission factors are compared with IPCC default values. Due to the data confidentiality the IEFs cannot be tabulated in here. The production data is gathered from the producer itself and it is compared with TurkStat's national production statistics. Both comparisons are found to be consistent.

**Recalculation:**

In the previous inventory, the producer provided the total metal production including the secondary productions for 2005-2013. This year the metal production data of the company revised and only the primary metal production was taken into consideration. Moreover, recalculation was made due to a formulation mistake for 1990 to 2012 for F-gases. Also PFC, $C_2F_6$ and $CF_4$ emission factors are recalculated in Eti Aluminum Facility in 2015-2016, calculation made by using the current coefficients in the Greenhouse Gas Monitoring Reporting Communiqué. The unit of the total emission is $CO_2$ eq. for PFCs, $CF_4$ and $C_2F_6$ emissions from primary aluminum production.

**Planned Improvements:**

No further improvements are planned at this time.

### 4.4.4. Magnesium production (Category 2.C.4)

There is no magnesium production in Turkey during period 1990-2018.

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

#### Source Category Description

There are two primary processes for the production of rough lead bullion from lead concentrates. The first type is sintering/smelting, which consists of sequential sintering and smelting steps and constitutes roughly 78% of world-wide primary lead production. The second type is direct smelting, which eliminates the sintering step and constitutes the remaining 22% of primary lead production in the developed world. However, in Turkey there is no primary lead production. Turkey is producing lead by only smelting the recycled lead from vehicles' old batteries. Turkey's highways are developed and there are over 20 million registered highway vehicles and there is huge amount of vehicle batteries to be recycled every year. Therefore, there are many lead batteries recycling companies in Turkey.

In lead recycling the batteries are crushed and then the scrap lead and plastic contents are separated by floating. Then the lead is put into a smelting furnace with some reductant agent (natural gas, fuel oil or metallurgical coke), silica, and iron. The furnace is heated up and the lead is melted in the furnace. During this process oxides are carbonated and leave the furnace as $CO_2$.

#### Methodological Issues:

Lead production is not a key category in Turkey, and due to lack of data, the Tier 1 is applied to calculate $CO_2$emissions by multiplying process specified to lead production data, as shown in equation below.

$$E_{CO2} = Pb * EF_{secondary\ raw\ material\ treatment}$$

where:
$E_{CO2}$ = $CO_2$ emissions from lead production, tonnes
Pb= quantity of lead produced, tonnes
EF secondary raw material treatment = process specific emission factor, tonnes $CO_2$ / tonne lead produced

The lead production data is known for only 1990-1996. Besides that, the amount of vehicle batteries recycled is known for the years 2007 and 2016. There is no data between 1997 and 2006. The specialists from the production field say that lead production amount is 60% of the vehicle batteries recycled by weight and this assumption is used for the estimation of secondary lead production. The amount of lead produced between 1997 and 2006 is estimated by interpolation.

**Collection of activity data**

There are many companies in Turkey recycling vehicle batteries for lead recovery. Since old batteries are classified as dangerous waste, it is statistically overseen. The amount of vehicle batteries recycled in Turkey is known for the years 2007-2018. The data is gathered from Ministry of Environment and Urbanization. It is assumed that 60% of the waste battery weight is recycled as lead. This assumption is based on the experts who work in the lead smelting industry. 1990-1996 lead production data is found in the 8th five years development plant of Turkey. The data for the years 1997-2006 are estimated by interpolation. In the table below the amount of vehicle batteries recycled and consequently the amount of lead produced in the smelting process is shown. The emissions from lead production is also shown in the same table.

**Table 4.33 Lead production of Turkey and $CO_2$ emissions from lead production, 1990-2018**

| Year | Recycled waste batteries (kt) | Lead production from waste batteries (kt) | $CO_2$ emissions (kt) |
|---|---|---|---|
| 1990 | No Data | 11.0 | 2.2 |
| 1991 | No Data | 8.5 | 1.7 |
| 1992 | No Data | 10.5 | 2.1 |
| 1993 | No Data | 9.6 | 1.9 |
| 1994 | No Data | 8.7 | 1.7 |
| 1995 | No Data | 11.1 | 2.2 |
| 1996 | No Data | 13.4 | 2.7 |
| 1997 | No Data | 14.7 | 2.9 |
| 1998 | No Data | 16.0 | 3.2 |
| 1999 | No Data | 17.2 | 3.4 |
| 2000 | No Data | 18.5 | 3.7 |
| 2001 | No Data | 19.7 | 3.9 |
| 2002 | No Data | 21.0 | 4.2 |
| 2003 | No Data | 22.3 | 4.5 |
| 2004 | No Data | 23.5 | 4.7 |
| 2005 | No Data | 24.8 | 5.0 |
| 2006 | No Data | 26.0 | 5.2 |
| 2007 | 45.5 | 27.3 | 5.5 |
| 2008 | 48.5 | 29.1 | 5.8 |
| 2009 | 53.0 | 31.8 | 6.4 |
| 2010 | 55.0 | 33.0 | 6.6 |
| 2011 | 59.4 | 35.6 | 7.1 |
| 2012 | 59.5 | 35.7 | 7.1 |
| 2013 | 69.0 | 41.4 | 8.3 |
| 2014 | 61.3 | 36.8 | 7.4 |
| 2015 | 71.4 | 42.9 | 8.6 |
| 2016 | 66.4 | 39.8 | 8.0 |
| 2017 | 73.9 | 44.3 | 8.9 |
| 2018 | 72.6 | 40.5 | 8.1 |

**Choice of emission factor**

Emission factor of 0.20 tonne of $CO_2$ / tonne of lead produced is used in the calculations. This is the process type specific emission factor for the treatment of secondary raw materials in the 2006 IPCC Guidelines, Table 4.21.

### Uncertainties and Time-Series Consistency:

National production data for the amount of vehicle batteries are used as the activity data and it is estimated that 60% by weight of the amount of batteries recycled is recovered as lead. Due to this assumption the activity data has an uncertainty of 25% relying on the expert judgment. The process type emission factor has an uncertainty of 20% by default.

In this submission, uncertainty in $CO_2$ emissions from category 2.C.5 was quantified using the Monte Carlo simulation for the first time with other IPPU sub-categories. Combined uncertainty in $CO_2$ emissions in 2018 is estimated at -22.87% to +24.60%. Further information about Monte Carlo analysis of lead production can be seen in Uncertainty chapter (Annex 2).

### Source-Specific QA/QC and Verification:

The weight data of recycled batteries is gathered from Ministry of Environment and Urbanization (MEU). The same data is also produced by TurkStat. When this two data sets from different sources are compared they are found to be only 3% different.

In order to estimate the amount of lead produced using the amount of batteries recycled data, the biggest two lead smelter company were asked and the production engineers and environmental responsibles gave necessary information. One company responsible declared 55-60% of lead recovery, the other company declared 65% of lead recovery from the old vehicle batteries by weight. Therefore, these information is consistent with the assumption that 60% of lead is recovered by weight. In this submission emission calculation was done by using two different calculation tools by two people. One is typically excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

### Recalculation:

There is no recalculation for this year's inventory.

### Planned Improvements:

Research will be held for decreasing the uncertainty in the activity data.

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

### Source Category Description:

In Turkey currently there is no zinc production. In the past, there was a single primary production plant (ÇİNKUR), located in Kayseri, produced zinc until 1999, starting from 1968. The company was closed in 1999. The plant produced zinc by utilizing zincoxide ore by pyrometallurgical (Imperial Smelting Furnace) process. The table below shows the amount of zinc production and $CO_2$ emissions.

**Table 4.34 Zinc productions and $CO_2$ emission, 1990-2018**

| Year | Zinc Production (kt) | $CO_2$emission (kt) |
|---|---|---|
| 1990 | 22.0 | 37.84 |
| 1991 | 17.2 | 29.58 |
| 1992 | 20.8 | 35.78 |
| 1993 | 20.4 | 35.09 |
| 1994 | 20.8 | 35.78 |
| 1995 | 20.4 | 35.09 |
| 1996 | 20.8 | 35.78 |
| 1997 | 37.6 | 64.67 |
| 1998 | 35.6 | 61.23 |
| 1999 | 31.2 | 53.66 |
| 2000-2018 | NO | NO |

NO = Not Occurred

In 1996 the production plant was privatized. It is seen that by 1997 the plant increased its production and so its emissions. The plant stopped its primary zinc production line by December 1999.

### Methodological Issues:

Zinc production is not a key category in Turkey, and due to lack of data Tier 1 is applied. In order to calculate $CO_2$emissions, the default EF is multiplied with zinc production data as shown in the equation below.

$$E_{CO2} = ZN * EF_{default}$$

where:
$E_{CO2}$ = $CO_2$ emissions from zinc production, tonnes
Zn = quantity of zinc produced, tonnes
EF default = Default emission factor, tonnes $CO_2$/ tonne zinc produced

**Collection of activity data**

The Plant stopped its primary zinc production activities in 1999. And it changed its owners many times from then. The newest owners of the plant have no information dating back to those years. Fortunately, the capacity utilization rate and the total zinc production capacity of the plant is found in the records of the ministry of state responsible for privatization (2001). By multiplying the production capacity of the plant with the capacity utilization rate, the production data of the plant are estimated for 1990-1999.

**Choice of emission factor**

Default emission factor of 1.72 tonne of $CO_2$ / tonne of zinc produced is used in the calculations. This is the default emission factor in the 2006 IPCC Guidelines, Table 4.24 based on weighting of 60% Imperial Smelting and 40% Waelz Kiln.

### Uncertainties and Time-Series Consistency:

Uncertainty value for EF is considered 50% as recommended in the 2006 IPCC Guidelines Volume 3 Table 4.25 due to the use of default EF. The capacity data of zinc production plant is different in two separate data sources. (33.500 tonnes/year in the 8th Five Years of Development Plan of Turkey and 40.000 tonnes/year in our data source). Since the production data is calculated as the capacity of the plant multiplied by the capacity utilization rate, the AD should have a higher uncertainty then the Guideline recommends. Uncertainty value for AD is considered 20% based on the expert judgment.

### Source-Specific QA/QC and Verification:

Experts from zinc trader and waelz oxide producer companies in Turkey are personally communicated and by this way it is verified that Turkey's only zinc producer was ÇİNKUR and it was closed in 1999. ÇİNKUR's zinc production data is also found in the 8th five years development plan of Turkey (2001) and it is stated that ÇİNKUR is roughly producing 20.000 tons zinc/year which is in line with our calculated production data for the years between 1990 and 1996. In this submission emission calculation was done by using two different calculation tools by two people. One is typically excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

### Recalculation:

There is no recalculation for this submission.

### Planned Improvements:

No further improvements are planned at this time.

## 4.5. Non-Energy Products from Fuels and Solvent Use (Category 2.D)

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

#### Source Category Description:

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

The use of lubricants in engines is primarily for their lubricating properties and associated emissions are therefore considered as non-combustion emissions and reported in the IPPU Sector.

#### Methodological Issues:

$CO_2$ emissions calculation is based on the amount of lubricant consumption in a country which is obtained from IEA - Eurostat - UNECE Energy Questionnaire - Oil table of Turkey. Having only total consumption data for all lubricants (i.e. no separate data for oil and grease), the weighted average oxidation during use (ODU) factor and default carbon content factor for lubricants as a whole is used as default value for the calculation. T1 method which is formulated by Equation 5.2 in 2006 IPCC Guidelines is used to calculate $CO_2$ emission. The amount of lubricant consumed in terms of kt converted to in terms of TJ by multiplying it with a factor (40.2). The following table shows the amount of lubricant used and the $CO_2$ emissions, from 1990 to 2018.

**Table 4.35 The Amount of lubricant used and $CO_2$ emissions, 1990-2018**

| | | (kt) |
|---|---|---|
| **Year** | **Lubricant** | **$CO_2$** |
| 1990 | 297 | 175.1 |
| 1991 | 310 | 182.8 |
| 1992 | 270 | 159.2 |
| 1993 | 287 | 169.2 |
| 1994 | 290 | 171.0 |
| 1995 | 339 | 199.9 |
| 1996 | 371 | 218.7 |
| 1997 | 406 | 239.4 |
| 1998 | 340 | 200.5 |
| 1999 | 420 | 247.6 |
| 2000 | 460 | 271.2 |
| 2001 | 335 | 197.5 |
| 2002 | 447 | 263.6 |
| 2003 | 437 | 257.7 |
| 2004 | 571 | 336.7 |
| 2005 | 667 | 393.3 |
| 2006 | 747 | 440.4 |
| 2007 | 733 | 432.2 |
| 2008 | 591 | 348.5 |
| 2009 | 652 | 384.4 |
| 2010 | 713 | 420.4 |
| 2011 | 1 416 | 834.9 |
| 2012 | 998 | 588.4 |
| 2013 | 894 | 527.1 |
| 2014 | 654 | 385.6 |
| 2015 | 432 | 254.7 |
| 2016 | 229 | 135.0 |
| 2017 | 243 | 143.3 |
| 2018 | 328 | 193.4 |

### Uncertainties and Time-Series Consistency:

Because the default ODU factors developed are very uncertain, as they are based on limited knowledge of typical lubricant oxidation rates, the default uncertainty for EF is 50%. For AD uncertainty value is considered to be25%.

An uncertainty analysis using the Monte Carlo technique was carried out to estimate emissions of $CO_2$ for 2.D.1 category and also to other IPPU categories in 2020 inventory year. Combined uncertainty of $CO_2$ emissions in 2018 is estimated at the range of -51.96% to +59.43%. Please refer to Annex 2 for more detailed information.

### Source-Specific QA/QC and Verification:

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates and on proper use of

notation keys in the CRF tables according to QA/QC plan. In this submission emission calculation was done by using two different calculation tools by two people. One is typically excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

**Recalculation:**

No recalculation is made for this category.

**Planned Improvements:**

No further improvements are planned at this time.

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

**Source Category Description:**

The category, as defined here, includes such products as petroleum jelly, paraffin waxes and other waxes, including ozokerite (mixtures of saturated hydrocarbons, solid at ambient temperature). Paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils. Paraffin waxes are categorized by oil content and the amount of refinement.

Waxes are used in a number of different applications. Paraffin waxes are used in applications such as: candles, corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffin are combusted during use (e.g., candles), and when they are incinerated with or without heat recovery or in wastewater treatment (for surfactants). In this submission emission calculation was done by using two different calculation tools by two people. One is typically excel based while the other is oracle and software coding based. The results of two different tool was compared to minimize calculation error.

**Methodological Issues:**

$CO_2$ emissions calculation is based on the amount of paraffin waxes consumed in a country which is obtained from IEA - Eurostat - UNECE Energy Questionnaire - Oil table of Turkey. Tier 1 method formulated as Equation 5.4 in 2006 IPCC Guidelines is used with default carbon content and ODU factor. The following table shows the amount of paraffin wax used and resulting $CO_2$ emissions, 1990 to 2018.

**Table 4.36 The Amount of paraffin wax used and $CO_2$ emissions, 1990-2018**

(kt)

| Year | Paraffin wax use | $CO_2$ |
|---|---|---|
| 1990 | 14 | 8.3 |
| 1991 | 13 | 7.7 |
| 1992 | 7 | 4.1 |
| 1993 | 8 | 4.7 |
| 1994 | 5 | 2.9 |
| 1995 | 5 | 2.9 |
| 1996 | 8 | 4.7 |
| 1997 | 5 | 2.9 |
| 1998 | 5 | 2.9 |
| 1999 | 4 | 2.4 |
| 2000 | 10 | 5.9 |
| 2001 | 28 | 16.5 |
| 2002 | 33 | 19.5 |
| 2003 | 29 | 17.1 |
| 2004 | 38 | 22.4 |
| 2005 | 89 | 52.5 |
| 2006 | 53 | 31.2 |
| 2007 | 29 | 17.1 |
| 2008 | 19 | 11.2 |
| 2009 | 20 | 11.8 |
| 2010 | 19 | 11.2 |
| 2011 | 32 | 18.9 |
| 2012 | 29 | 17.1 |
| 2013 | 11 | 6.5 |
| 2014 | 23 | 13.6 |
| 2015 | 20 | 11.8 |
| 2016 | 19 | 11.2 |
| 2017 | 14 | 8.3 |
| 2018 | 22 | 13 |

### Uncertainties and Time-Series Consistency:

Uncertainty values of AD is considered to be 25%, on the other hand since the ODU factor is highly dependent on specific country conditions and policies, the default EF exhibits an uncertainty of 100% according to the 2006 IPCC Guidelines.

Additionally, an uncertainty analysis using the Monte Carlo technique was carried out to estimate emissions of $CO_2$ for 2.D.2 category (Paraffin wax use) in 2020 inventory year. Combined uncertainty in $CO_2$ emissions in 2018 is estimated at the range of (-98.46%,+107.31%). For more detailed information please refer to Annex 2.

### Source-Specific QA/QC and Verification:

During the preparation of the inventory submission, activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates and on proper use of notation keys in the CRF tables according to QA/QC plan.

### Recalculation:

No recalculation is made for this category.

### Planned Improvements:

No further improvements are planned at this time.

## 4.6. Electronics Industry (Category 2.E)

A research for this category, has been done by taking into consideration of relevant sectors and gases. According to the results, it has been appeared that F-gases have not been used in the manufacturing processes of these sectors. However, it is founded that some gases have been used with the aim of research and development.

### Source category description

The sub-sector only consists of the following sub-application: 2.E.5- Other, other electronic uses.

### Methodological issues

This section is composed of results of the research which has been conducted by the Ministry of Environment and Urbanization. As it is stated above, results show that F-gases are not used in the manufacturing of flat panel display, photovoltaic products and semiconductors. This information has been gathered by contacting with largest companies within the relevant sectors.

However, it is observed that $CF_4$, $CHF_3$ and $SF_6$ are used for the research and development in the area of semiconductor products. Therefore, these gases are reported under the category of 2.E.5 "other electronic uses".

According to the research, these gases were started to be used in 2010. For reporting of emission, it is assumed that same amount of gas was used for each year. This assumption is made by considering the

expert judgment. MoEU has made survey with the leading company of Turkey, which is, has R&D department in electronic industry and the numbers is assessed due to the results of survey.

Table 4.37 shows the consumption amount of each gases which are consumed for the research and development purpose.

**Table 4.37 Consumption of each gases, 2018**

(kg)

| | $CF_4$ | HFC-23 | $SF_6$ |
|---|---|---|---|
| 2010 | 1.2 | 6 | 1 848 |
| 2011 | 1.2 | 6 | 1 848 |
| 2012 | 1.2 | 6 | 1 848 |
| 2013 | 1.2 | 6 | 1 848 |
| 2014 | 1.2 | 6 | 1 848 |
| 2015 | 1.2 | 6 | 1 848 |
| 2016 | 1.2 | 6 | 1 848 |
| 2017 | 1.28 | 6.4 | 1 984.7 |
| 2018 | 1.31 | 6.56 | 2 501.7 |

Turkey's economy grew 2.6 percent in 2018 and the value of consumption of each gas has determined for 2018 by using the value of economic grew.

### Recalculation:

There is recalculation in 2.E.5 for $SF_6$, HFC-23 and $CF_4$ due to unit error in CRF data entry.

## 4.7. Product Use as Substitutes for ODS (Category 2.F)

### Source Category Description:

Production of fluorochemicals does not exist in Turkey. Therefore, all demand for these gases is met by imports.

The sub sector emissions of fluorinated substitutes for ODS consist of the following sub application;

- 2F3 emissions from fire protection
- 2F6 emissions from other applications

### Methodological Issues:

The methodology used to estimate HFCs emissions from the sub-sector has been based on the 2006 IPCC Guidelines, using the model provided by the IPCC, which calculate emissions following T1 method. Inventory calculations have been based on the raw trade data (import and export) provided for each gas by Ministry of Trade.

It should be noted that HFCs are being used as alternatives to CFCs since 1999. Since then it is thought that HFCs are used in different industrial sectors. However due to lack of information, it is assumed that most of HFCs gases, excluding HFC-227ea that is used only in fire extinguishers, are used in refrigeration and air conditioning sector. Due to this reason, these gases are calculated according to the calculation assumptions for refrigeration and air conditioning but calculation results are reported under "Other Applications" title in 2F category.

As it is written in 2006 IPCC Guidelines, following assumptions are used in a hybrid Tier 1a/b approach for calculations;

- Servicing of equipment containing the refrigerant does not commence until 3 years after the equipment is installed.
- Emissions from banked refrigerants average 3 % annually across the whole refrigeration and air conditioning application area.
- In a market, two thirds of the sales of a refrigerant are used for servicing and one third is used to charge new equipment.
- The average equipment lifetime is 15 years.
- The complete transition to a new refrigerant technology will take place over a 10 years period.

For calculation of HFC-227ea, expert judgments are considered. According to the information which is obtained from discussion with experts who are working under the Protection of Ozon Layer Division of MoEU and Turkish Fire Protection and Training Foundation – (TUYAK) which is representative of fire sector, HFC-227ea is mostly consumed in fire protection application in Turkey. Regarding to this information, this gas is reported under "2F3 Fire Protection" category. As it is stated in the 2006 IPCC Guideline, HFCs in this application area, are emitted over a period longer than one year. To consider this, spreadsheet which is proposed by guideline is used for calculation.

### Uncertainties and Time-Series Consistency:

Table 4.38 and Figure 4.19 present total HFCs emissions from 1999 to 2018. Increasing trend in emissions is clearly observed from these presentations. The reason behind this can be explained by the prohibition of CFCs in the country. Since 1999, HFCs have been used as substitution of CFCs (Values of 1999 has been calculated due to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories).

**Table 4.38 Total HFCs emissions, 2010-2018**

| Year | HFCs Emissions (tonnes) | HFCs Emissions (kt $CO_2$ eq.) |
|---|---|---|
| 1999 | 42.7 | 60.8 |
| 2000 | 81.3 | 115.66 |
| 2001 | 163.4 | 232.00 |
| 2002 | 293.9 | 417.19 |
| 2003 | 443.2 | 628.80 |
| 2004 | 640.8 | 909.37 |
| 2005 | 808.6 | 1 146.88 |
| 2006 | 1 004.4 | 1 424.19 |
| 2007 | 1 208.4 | 1 713.19 |
| 2008 | 1 348.1 | 1 896.14 |
| 2009 | 1 621.3 | 2 111.28 |
| 2010 | 2 412.4 | 3 054.19 |
| 2011 | 2 949.9 | 3 432.55 |
| 2012 | 3 654.4 | 4 256.75 |
| 2013 | 4 029.9 | 4 470.16 |
| 2014 | 4 489.2 | 4 927.46 |
| 2015 | 4 511.9 | 4 804.95 |
| 2016 | 4 405.7 | 4 719.53 |
| 2017 | 4 766.3 | 4 744.55 |
| 2018 | 4 467.3 | 4 697.65 |

**Figure 4.19 Total HFCs emissions, 2000-2018**

Above presentation shows aggregated emissions caused by HFCs including HFC-23, HFC-32, HFC-41, HFC-43-10mee, HFC-125, HFC-134, HFC-134a, HFC-143, HFC-143a, HFC-152a, HFC-227ea, HFC-236fa, HFC-245ca, and HFC-365mfc. Moreover, table below separately indicates emissions from these gases for specific years. All emission values are presented in tonnes and for each gas emissions are calculated related to Tier 1a/1b method of IPCC. Inventory calculations have been based on the raw trade data (import and export) provided for each gas by Ministry of Trade and the change in graph is consistent with number of import and export.

**Table 4.39 HFCs Emissions** **(t)**

| Substance | 2000 | 2005 | 2010 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|---|
| **HFC-23** | 0.02 | 0.29 | 0.56 | 4.64 | 4.05 | 3.61 | 3.24 | 2.93 | 2.01 |
| **HFC-32** | - | - | - | 0.01 | 0.236 | 0.201 | 1.625 | 4.28 | 151.41 |
| **HFC-41** | - | - | 0.03 | 0.03 | 0.0217 | 0.6640 | 0.5644 | 0.4798 | 0.3568 |
| **HFC-43-10mee** | - | - | - | 0.07 | 0.1464 | 0.124 | 0.330 | 0.731 | 1.7 |
| **HFC-125** | - | - | 0.71 | 6.68 | 14.180 | 24.180 | 30.863 | 34.724 | 37.48 |
| **HFC-134** | - | - | - | 0.01 | 0.0046 | 0.0039 | 0.0034 | 0.0029 | 0.002 |
| **HFC-134a** | 80.35 | 791.38 | 2 066.27 | 2877.47 | 3056.82 | 2904.74 | 3128.67 | 3192.67 | 2997.81 |
| **HFC-143** | - | - | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.00 | 0.00 |
| **HFC-143a** | - | - | - | 0.000 | 0.000 | 2.83 | 3.83 | 3.25 | 3.90 |
| **HFC-152a** | 0.78 | 14.07 | 331.36 | 1109.14 | 1139.461 | 1268.482 | 1376.52 | 1466.61 | 1729.9 |
| **HFC-236fa** | - | - | 0.68 | 4.12 | 4.105 | 4.090 | 4.601 | 5.56 | 8.48 |
| **HFC-245ca** | - | - | 0.02 | 0.82 | 2.6539 | 2.2557 | 1.9174 | 1.6298 | 1.42 |
| **HFC-245fa** | - | - | - | - | 10.67 | 11.81 | 10.65 | 0.00 | 0.00 |
| **HFC-365mfc** | - | - | 0.12 | 0.92 | 0.78 | 0.66 | 0.56 | 0.4798 | 0.41 |
| **HFC-227ea** | 0.13 | 2.87 | 12.67 | 26.06 | 33.23 | 39.33 | 43.17 | 53.44 | 66.88 |

The calculation method is IPCC T1 for all substances given above.

Inventory calculations have been based on the raw trade data (import and export) provided for each gas by Ministry of Trade and the change in emission values are consistent with number of import and export.

**Figure 4.20 HFC-227ea Emissions, 2000-2018**

### Recalculation:

There is recalculation for HFC 32 and HFC 43.10.mee due to unit error in CRF data entry in 2.F.6.

### Planned Improvement:

For the future inventory submissions, improvements in the sector data will be done within the scope of *Technical Assistance for Increased Capacity for Transposition and Capacity Building on F-Gases Project* which has started in 2017 and will last in 2020.

## 4.8. Other Product Manufacture and Use (Category 2.G)

### Source Category Description:

The sub-sector other product manufacture and use consists of the following sub- applications:

- 2.G.1- $SF_6$ Emissions from electrical equipment

### Methodological Issues:

It is assumed that $SF_6$ is used only in electrical instruments, mainly in circuit breakers. Emission results are reported based on the import and export data of $SF_6$. However, custom code for this gas was established in 2013 and trade data is available only for 2013- 2018. Therefore, trend of electricity consumption is used for the prediction of imported gas for previous years.

Data for electricity consumption is obtained from the Turkish Electricity Transmission Corporation and the trade data for $SF_6$ is provided by Ministry of Trade. Table 4.40 shows the distribution of electricity consumption, $SF_6$ consumption (import and export values) and emissions of $SF_6$ which is emitted from the circuit breakers used in Electricity industry. The IPCC default values of emission factors (including natural leakage and emissions of operation, maintenance, and disposal) are 2.6% for the EU, 0.7% for Japan, and 2.0% as a global average and calculation made by using the global average value.

**Table 4.40 $SF_6$ Consumption and Electricity Consumption**

| Years | Electricity consumption (GWh) | $SF_6$ net consumption (tonnes) | $SF_6$ Emissions (tonnes) |
|---|---|---|---|
| 1996 | 74 157 | 22.075 | 0.441 |
| 1997 | 81 885 | 24.375 | 0.487 |
| 1998 | 87 705 | 26.108 | 0.522 |
| 1999 | 91 202 | 27.149 | 0.542 |
| 2000 | 98 296 | 29.260 | 0.585 |
| 2001 | 97 070 | 28.895 | 0.577 |
| 2002 | 102 948 | 30.645 | 0.612 |
| 2003 | 111 766 | 33.270 | 0.665 |
| 2004 | 121 142 | 36.061 | 0.721 |
| 2005 | 130 263 | 38.776 | 0.775 |
| 2006 | 143 071 | 42.589 | 0.851 |
| 2007 | 155 135 | 46.180 | 0.923 |
| 2008 | 161 948 | 48.208 | 0.964 |
| 2009 | 156 894 | 46.703 | 0.934 |
| 2010 | 172 051 | 51.215 | 1.024 |
| 2011 | 186 100 | 55.397 | 1.107 |
| 2012 | 194 923 | 58.024 | 1.160 |
| 2013 | 198 045 | 58.953 | 1.179 |
| 2014 | 207 375 | 71.826 | 1.436 |
| 2015 | 216 233 | 87.055 | 1.741 |
| 2016 | 225 495 | 80.002 | 1.600 |
| 2017 | 249 020 | 160.277 | 3.205 |
| 2018 | 254 863 | 156 591 | 3.131 |

There is no information about the number and the capacity of the used, imported or exported equipments and the number of destroyed equipments. The imported gas amount has been assumed as

2% emitted in related year. Net consumption of SF6 is almost doubled by year 2018 when comparing with year 2016, import and export data is provided by Ministry of Trade.

**Figure 4.21 $SF_6$ emissions, 1996-2018**

### Uncertainties and Time-Series Consistency:

Uncertainties of $SF_6$ was estimated using expert judgment as described in IPCC Good Practice Guidance and Uncertainty Management (2000) Reference.

### Source-Specific QA/QC and Verification:

During the preparation of the inventory submission activities related to source specific quality control were mainly focused on completeness and consistency of emission estimates and on proper use of notation keys in the CRF tables according to QA/QC plan. Aggregated national EFs are compared with IPCC default values.

### Recalculation:

There is no recalculation for this submission.

### Planned Improvement:

For the future inventory submissions, improvements in the sector data will be done within the scope of *Technical Assistance for Increased Capacity for Transposition and Capacity Building on F-Gases Project* which has started in 2017 and will last in 2020.

# 5. AGRICULTURE (CRF Sector 3)

## 5.1. Sector Overview

Agricultural activities will most likely coexist with the existence of human beings on this planet, and agricultural production is indispensable to the continuance of life. Effects of climate change are observed by concentration of GHGs for many sectors including agriculture which generally comes second in size after the energy sector. The total emission value calculated for the agriculture sector is 64.9 Mt $CO_2$ eq. for the year 2018 which is 15.2% of the total emission value including LULUCF sector and 12.5% of all emissions excluding LULUCF sector for the Republic of Turkey. The agricultural sector is divided into ten categories from 3.A to 3.J in the CRF tables. These categories are listed in Table 5.1 briefly for GHGs emitted from each of these sources.

**Table 5.1 Categories of the agriculture sector and emitted gases**

| CRF Categories | | $CO_2$ | $CH_4$ | $N_2O$ | $NO_x$ | CO | NMVOC | $SO_x$ |
|---|---|---|---|---|---|---|---|---|
| 3.A | Enteric fermentation | | x | | | | | |
| 3.B | Manure management | | x | x | x[b] | | x[b] | |
| 3.C | Rice cultivation | | x | | | | | |
| 3.D | Agricultural soils | x[a] | | x | x[b] | | x[b] | |
| 3.E | Prescribed burning of savannas | | x | x | x[c] | x[c] | x[c] | x[c] |
| 3.F | Field burning of agricultural residues | | x | x | x[b] | x[b] | x[b] | x[b] |
| 3.G | Liming | x | | | | | | |
| 3.H | Urea application | x | | | | | | |
| 3.I | Other carbon-containing fertilizers | x | | | | | | |
| 3.J | Other | | | | | | | |

[a] to be reported under LULUCF Sector.
[b] Emissions of this gas from this category are likely to be emitted and a methodology is provided in the EMEP/EEA Guidebook.
[c] Emissions of this air pollutant from this category are likely to be emitted and the methodology may be included in the EMEP/EEA Guidebook in the future.

The percentage of emissions from this sector as percentage of total national GHG emissions (excluding LULUCF) gradually declined from 20.9% to 10.6% in most of the years between 1990 and 2009 before levelling off and thereafter gaining a momentum. With the aim to give a clear view on the weights of the categories within the sector, the following Table 5.2 presents emission and percentage values for the year 2018.

**Table 5.2 Agriculture sector emissions and overall percentages by categories, 2018**

| | $CH_4$ (kt $CO_2$ eq.) | $N_2O$ (kt $CO_2$ eq.) | $CO_2$ (kt) | Total (kt $CO_2$ eq.) | (%) |
|---|---|---|---|---|---|
| **3 Agriculture** | **36 323** | **27 292** | **1 257** | **64 872** | **100.0** |
| A. Enteric fermentation | 32 060 | | | 32 060 | 49.4 |
| B. Manure management | 3 886 | 4 557 | | 8 443 | 13.0 |
| C. Rice cultivation | 252 | | | 252 | 0.4 |
| D. Agricultural soils | | 22 697 | | 22 697 | 35.0 |
| E. Prescribed Burning of Savannas | | | | NO | |
| F. Field burning of agricultural residues | 124 | 38 | | 163 | 0.3 |
| G. Liming | | | | NE* | |
| H. Urea application | | | 1 257 | 1 257 | 1.9 |
| I. Other Carbon-containing fertilizers | | | | NO | |
| J. Other | | | | NO | |
| **GHG Percentage Shares** | 56.0 | 42.1 | 1.9 | 100.0 | |

*The emission level from source category 3.G Liming is considered to be insignificant according to Paragraph 37(b) of 24/CP.19.
Figures in the table may not add up to the totals due to rounding.

Table 5.3 clearly presents the developments of the emissions for the agriculture sector. The overall emission value for the sector increased from approximately 45.8 Mt $CO_2$ eq. to around 64.9 Mt $CO_2$ eq. (an increase of 41.5%) during the 29 years period after 1990. The biggest increase among the categories in absolute terms for the emissions is observed in the enteric fermentation category where the emissions increased by around 9.7 Mt $CO_2$ eq. (43.7%) from 22.3 Mt $CO_2$ eq. to 32.1 Mt $CO_2$ eq. for the same period. The primary reason for this increase is the change in activity data. Other significant increases in this twenty-nine years period are seen in agricultural soils, manure management, and urea application where the figures are 5.5 Mt $CO_2$ eq. (32%), 3 Mt $CO_2$ eq. (55.4%), and 0.8 Mt $CO_2$ eq. (173.4%), respectively. Increases in emissions from enteric fermentation and manure management are largely a result of changes in activity data. Emissions for rice cultivation increased by around 0.2 Mt $CO_2$ eq. (151.9%) whereas the emissions for field burning of agricultural residues between 1990 and 2018 resulted in a decrease of 53.1%.

**Table 5.3 Overview of agriculture sector emissions, 1990–2018**

| Year | A. Enteric fermentation | | B. Manure management | | C. Rice cultivation | | D. Agricultural soils | | F. Field burning | | H. Urea application | | Agriculture total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$) | (%) | (kt $CO_2$ eq.) | (%) |
| 1990 | 22 314 | 48.7 | 5 432 | 11.8 | 100 | 0.2 | 17 196 | 37.5 | 347 | 0.8 | 460 | 1.0 | 45 849 | 100 |
| 1991 | 23 129 | 49.5 | 5 660 | 12.1 | 100 | 0.2 | 17 043 | 36.5 | 359 | 0.8 | 436 | 0.9 | 46 727 | 100 |
| 1992 | 22 929 | 49.0 | 5 535 | 11.8 | 94 | 0.2 | 17 411 | 37.2 | 341 | 0.7 | 459 | 1.0 | 46 769 | 100 |
| 1993 | 22 536 | 47.7 | 5 602 | 11.9 | 102 | 0.2 | 17 969 | 38.1 | 367 | 0.8 | 627 | 1.3 | 47 203 | 100 |
| 1994 | 22 235 | 49.7 | 5 799 | 13.0 | 90 | 0.2 | 15 821 | 35.4 | 321 | 0.7 | 453 | 1.0 | 44 717 | 100 |
| 1995 | 21 705 | 49.5 | 5 523 | 12.6 | 113 | 0.3 | 15 750 | 35.9 | 332 | 0.8 | 426 | 1.0 | 43 848 | 100 |
| 1996 | 21 677 | 48.7 | 5 577 | 12.5 | 126 | 0.3 | 16 282 | 36.6 | 344 | 0.8 | 534 | 1.2 | 44 540 | 100 |
| 1997 | 20 204 | 47.8 | 5 161 | 12.2 | 124 | 0.3 | 15 898 | 37.6 | 347 | 0.8 | 532 | 1.3 | 42 266 | 100 |
| 1998 | 19 781 | 45.4 | 5 360 | 12.3 | 135 | 0.3 | 17 216 | 39.5 | 382 | 0.9 | 658 | 1.5 | 43 532 | 100 |
| 1999 | 19 850 | 45.0 | 5 460 | 12.4 | 147 | 0.3 | 17 553 | 39.8 | 342 | 0.8 | 733 | 1.7 | 44 086 | 100 |
| 2000 | 19 124 | 45.4 | 5 151 | 12.2 | 128 | 0.3 | 16 777 | 39.8 | 340 | 0.8 | 617 | 1.5 | 42 138 | 100 |
| 2001 | 18 606 | 46.9 | 5 101 | 12.9 | 132 | 0.3 | 15 008 | 37.8 | 318 | 0.8 | 527 | 1.3 | 39 692 | 100 |
| 2002 | 16 878 | 45.1 | 4 530 | 12.1 | 135 | 0.4 | 14 986 | 40.1 | 328 | 0.9 | 527 | 1.4 | 37 384 | 100 |
| 2003 | 18 464 | 45.6 | 4 957 | 12.2 | 143 | 0.4 | 16 074 | 39.7 | 325 | 0.8 | 565 | 1.4 | 40 529 | 100 |
| 2004 | 18 957 | 46.1 | 4 570 | 11.1 | 156 | 0.4 | 16 449 | 40.0 | 359 | 0.9 | 632 | 1.5 | 41 123 | 100 |
| 2005 | 19 663 | 46.6 | 4 754 | 11.3 | 183 | 0.4 | 16 718 | 39.6 | 302 | 0.7 | 613 | 1.5 | 42 234 | 100 |
| 2006 | 20 331 | 46.6 | 4 978 | 11.4 | 212 | 0.5 | 17 213 | 39.5 | 294 | 0.7 | 592 | 1.4 | 43 620 | 100 |
| 2007 | 20 552 | 47.6 | 5 047 | 11.7 | 203 | 0.5 | 16 555 | 38.3 | 256 | 0.6 | 566 | 1.3 | 43 179 | 100 |
| 2008 | 20 057 | 48.9 | 4 889 | 11.9 | 216 | 0.5 | 15 054 | 36.7 | 259 | 0.6 | 565 | 1.4 | 41 039 | 100 |
| 2009 | 19 576 | 46.9 | 4 829 | 11.6 | 209 | 0.5 | 16 289 | 39.0 | 288 | 0.7 | 593 | 1.4 | 41 784 | 100 |
| 2010 | 20 912 | 47.4 | 5 357 | 12.1 | 202 | 0.5 | 16 814 | 38.1 | 219 | 0.5 | 645 | 1.5 | 44 149 | 100 |
| 2011 | 22 806 | 48.9 | 5 600 | 12.0 | 204 | 0.4 | 17 208 | 36.9 | 233 | 0.5 | 558 | 1.2 | 46 609 | 100 |
| 2012 | 25 740 | 49.2 | 6 383 | 12.2 | 249 | 0.5 | 19 097 | 36.5 | 224 | 0.4 | 640 | 1.2 | 52 332 | 100 |
| 2013 | 26 851 | 48.4 | 6 724 | 12.1 | 231 | 0.4 | 20 656 | 37.2 | 240 | 0.4 | 807 | 1.5 | 55 509 | 100 |
| 2014 | 27 094 | 48.5 | 7 019 | 12.6 | 230 | 0.4 | 20 504 | 36.7 | 215 | 0.4 | 788 | 1.4 | 55 850 | 100 |
| 2015 | 26 888 | 48.2 | 6 905 | 12.4 | 240 | 0.4 | 20 744 | 37.2 | 174 | 0.3 | 811 | 1.5 | 55 761 | 100 |
| 2016 | 26 923 | 46.0 | 7 007 | 12.0 | 243 | 0.4 | 22 880 | 39.1 | 164 | 0.3 | 1 295 | 2.2 | 58 514 | 100 |
| 2017 | 30 039 | 47.8 | 7 642 | 12.2 | 234 | 0.4 | 23 316 | 37.1 | 165 | 0.3 | 1 450 | 2.3 | 62 846 | 100 |
| 2018 | 32 060 | 49.4 | 8 443 | 13.0 | 252 | 0.4 | 22 697 | 35.0 | 163 | 0.3 | 1 257 | 1.9 | 64 872 | 100 |

Figures in the table may not add up to the totals due to rounding.

Furthermore, in relative terms, the biggest category in the agriculture sector is enteric fermentation having a 49.4% share for 2018, so it dominates the sector. In all reported years, 1990-2018, this category had an average share of 47.6% in the agriculture sector, starting with a share of 48.7% in 1990. The second biggest category is agricultural soils having a proportion of 35% for 2018 decreased from 37.1% in 2017. While having percentage shares of agricultural soils that range from 40.1% in 2002 and 35% in 2018, its average share for the entire reporting period of twenty-nine years is around 37.9%. Manure management's share presents somehow a more stable increasing trend, starting from 11.8% in 1990 and reaching 13% in 2018 having an average of 12.1%. The remaining categories, which are rice cultivation, field burning of agricultural residuals, and urea application, had emission shares of 0.4%, 0.3%, and 1.9% respectively for 2018. Though the share increased by around 78% for rice cultivation and 93% for urea application, the absolute terms were small and relative weights of these two categories were still low for the period 1990-2018. Despite these increasing values, the share for field burning of agricultural residues decreased from 0.8% to 0.3% for the reporting period. A graphical representation is given below in Figure 5.1, which displays the overall cumulative distribution and the trend for the reporting period of the agriculture sector. Other sources are calculated by the addition of emission estimations from rice cultivation, field burning, and urea application.

**Figure 5.1 Cumulative emissions of agricultural categories, 1990–2018**

Additionally, it should be noted that prescribed burning of savannas (CRF Category 3.E) does not occur in Turkey and is therefore not reported in this National Inventory Report whereas liming (CRF Category 3.G) is considered to be insignificant according to Paragraph 37(b) of 24/CP.19. Other carbon-containing fertilizers (CRF Category 3.I) are not occurring while the final category, other (CRF Category 3.J) in the agriculture sector, is an option to be used only if necessary. Figure 5.2 displays an overview of category shares and methods used for the agriculture sector.

**Figure 5.2 Category shares and methods used in the agriculture sector, 2018**

The methods used for the emission estimations in the agriculture sector except for cattle in enteric fermentation are Tier 1 (T1). The only Tier 2 (T2) method used in this sector is for emissions due to enteric fermentation of cattle which has a value of 25 857 kt $CO_2$ eq. This amount equals to around 39.9% of total emissions in the agriculture sector and 80.7% of total emissions in enteric fermentation which is the biggest subcategory in enteric fermentation as presented in Figure 5.2.

**Table 5.4 Agriculture sector emissions – comparison between 2017 and 2018**

| Source Category | 2017 | | 2018 | | Change | |
|---|---|---|---|---|---|---|
| | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) |
| **3. Agriculture Sector** | **62 846** | **100** | **64 872** | **100** | **2 026** | **3.2** |
| 3.A Enteric Fermentation | 30 039 | 47.8 | 32 060 | 49.4 | 2 021 | 6.7 |
| 3.B Manure Management | 7 642 | 12.2 | 8 443 | 13.0 | 801 | 10.5 |
| 3.C Rice Cultivation | 234 | 0.4 | 252 | 0.4 | 18 | 7.7 |
| 3.D Agricultural Soils | 23 316 | 37.1 | 22 697 | 35.0 | -619 | -2.7 |
| 3.F Field Burning | 165 | 0.3 | 163 | 0.3 | -2 | -1.2 |
| 3.H Urea Application | 1 450 | 2.3 | 1 257 | 1.9 | -193 | -13.3 |

Figures in the table may not add up to the totals due to rounding. Please note that two source categories (CRF 3.E and 3.I) are not occurring (NO), while another source category (CRF 3.G Liming) is not estimated (NE) because it is considered to be insignificant.

The emission values between latest of the two reporting years, 2017 and 2018, are given in Table 5.4 and in order to present a different perspective on the size changes of major agricultural categories, Figure 5.3 is also given. Major agricultural categories, enteric fermentation, manure management, and agricultural soils, are responsible for more than 95% of the emissions in the sector. Additionally, the main changes in minor agricultural categories are given in Figure 5.4.

**Figure 5.3 Trends in major categories of agriculture**

**Figure 5.4 Trends in minor categories of agriculture**

GHG emission values and their percentage shares in the agriculture sector, $CH_4$, $N_2O$ and $CO_2$, are given in Table 5.5. After its initial increase in 1991, emission values for $CH_4$ decrease in the eleven years (except in 1996 and 1999) until 2002. Thereafter, the overall increasing trend could be split into two phases: a moderate one until 2009 and a stronger one after 2009. Overall, the percentage share of $CH_4$ increased from 54.6% in 1990 to 56% in 2018.

The average share of $N_2O$ emissions were around 44.8% with respect to yearly total agricultural emission values. The emission values for $N_2O$ were 20 358 kt $CO_2$ eq. (44.4%) in 1990 and increased to an estimated value of 27 292 kt $CO_2$ eq. while taking a smaller share of 42.1% of total agricultural emissions in 2018. $N_2O$ emissions are due to manure management and agricultural soils source categories in the agricultural sector.

$CO_2$ emissions result only from urea application; have the smallest share in this sector, and ranges between 0.9% and 2.3% for the period 1990-2018. The highest value of $CO_2$ emissions occurred in 2018 with 1450 kt, while it has the smallest value in 1995 with 426 kt depending on the amount of urea applied. The corresponding value for the latest reporting year accounts for a share of 1.9%.

**Table 5.5 Overview of GHGs in the agriculture sector, 1990–2018**

| Year | $CH_4$ (kt $CO_2$ eq.) | $CH_4$ (%) | $N_2O$ (kt $CO_2$ eq.) | $N_2O$ (%) | $CO_2$ (kt) | $CO_2$ (%) | Total (kt $CO_2$ eq.) |
|---|---|---|---|---|---|---|---|
| 1990 | 25 031 | 54.6 | 20 358 | 44.4 | 460 | 1.0 | 45 849 |
| 1991 | 25 944 | 55.5 | 20 347 | 43.5 | 436 | 0.9 | 46 727 |
| 1992 | 25 614 | 54.8 | 20 696 | 44.3 | 459 | 1.0 | 46 769 |
| 1993 | 25 339 | 53.7 | 21 237 | 45.0 | 627 | 1.3 | 47 203 |
| 1994 | 25 230 | 56.4 | 19 034 | 42.6 | 453 | 1.0 | 44 717 |
| 1995 | 24 597 | 56.1 | 18 825 | 42.9 | 426 | 1.0 | 43 848 |
| 1996 | 24 620 | 55.3 | 19 385 | 43.5 | 534 | 1.2 | 44 540 |
| 1997 | 22 901 | 54.2 | 18 833 | 44.6 | 532 | 1.3 | 42 266 |
| 1998 | 22 686 | 52.1 | 20 188 | 46.4 | 658 | 1.5 | 43 532 |
| 1999 | 22 813 | 51.7 | 20 540 | 46.6 | 733 | 1.7 | 44 086 |
| 2000 | 21 845 | 51.8 | 19 675 | 46.7 | 617 | 1.5 | 42 138 |
| 2001 | 21 395 | 53.9 | 17 770 | 44.8 | 527 | 1.3 | 39 692 |
| 2002 | 19 281 | 51.6 | 17 576 | 47.0 | 527 | 1.4 | 37 384 |
| 2003 | 21 086 | 52.0 | 18 878 | 46.6 | 565 | 1.4 | 40 529 |
| 2004 | 21 258 | 51.7 | 19 233 | 46.8 | 632 | 1.5 | 41 123 |
| 2005 | 22 037 | 52.2 | 19 584 | 46.4 | 613 | 1.5 | 42 234 |
| 2006 | 22 818 | 52.3 | 20 210 | 46.3 | 592 | 1.4 | 43 620 |
| 2007 | 23 134 | 53.6 | 19 479 | 45.1 | 566 | 1.3 | 43 179 |
| 2008 | 22 579 | 55.0 | 17 895 | 43.6 | 565 | 1.4 | 41 039 |
| 2009 | 22 143 | 53.0 | 19 049 | 45.6 | 593 | 1.4 | 41 784 |
| 2010 | 23 752 | 53.8 | 19 751 | 44.7 | 645 | 1.5 | 44 149 |
| 2011 | 25 641 | 55.0 | 20 410 | 43.8 | 558 | 1.2 | 46 609 |
| 2012 | 28 997 | 55.4 | 22 695 | 43.4 | 640 | 1.2 | 52 332 |
| 2013 | 30 261 | 54.5 | 24 441 | 44.0 | 807 | 1.5 | 55 509 |
| 2014 | 30 652 | 54.9 | 24 411 | 43.7 | 788 | 1.4 | 55 850 |
| 2015 | 30 292 | 54.3 | 24 659 | 44.2 | 811 | 1.5 | 55 761 |
| 2016 | 30 404 | 52.0 | 26 814 | 45.8 | 1 295 | 2.2 | 58 514 |
| 2017 | 33 747 | 53.7 | 27 649 | 44.0 | 1 450 | 2.3 | 62 846 |
| 2018 | 36 323 | 56.0 | 27 292 | 42.1 | 1 257 | 1.9 | 64 872 |

Figures in the table may not add up to the totals due to rounding.

The activity data used for the compilation of the GHG inventory is provided mainly by TurkStat's databases distributed by its Central Dissemination System on the following website accessible on https://biruni.tuik.gov.tr/medas/?kn=101&locale=en which is also accessible on www.turkstat.gov.tr.

Livestock population data are critical activity data for the required calculations. Animal population numbers given in Table 5.6 and Table 5.7 are provided by TurkStat for the entire time series, 1990-2018. There are differences among population sizes (cattle, sheep and swine), between the numbers used for the estimations of GHG emissions and official numbers submitted to the Food and Agriculture Organization of the United Nations (FAO). The FAO data are slightly old and do not consider the most recent TurkStat data, which is used for the inventory submission. Therefore, the AD of the GHG inventory is more recent and accurate compared to FAO. Moreover, FAO have some assumptions on TurkStat data. Although, the data is updated in each year by TurkStat, FAO has still continued to use

their assumptions. Therefore, the data sent by TurkStat, which is also used for GHG inventory, is the most accurate data available for inventory calculations.

Data on livestock production have been collected from District Offices of the Ministry of Forestry and Agriculture at the end of the year. Since 2014, data on livestock numbers have been collected and published two times a year. The data, entered into an online database by the district offices, have been analyzed together with the Ministry of Forestry and Agriculture. Prepared data are sent to the Ministry for controlling process. Once again controlled data are analyzed by Agricultural Production Statistics group at TurkStat and will then become ready for publishing after final analysis and controls.

Livestock population numbers are given for livestock species in Table 5.6. As the numbers display, both dairy and non-dairy cattle, domestic sheep, poultry and goats have significantly high population numbers with respect to other livestock species. Four columns, which are dairy cattle, non-dairy cattle, sheep merino, and poultry, have positive differences between 1990 and 2018 with population increasing around 0.4 million (7.6%), 5.2 million (95.2%), 1.8 million (218.5%), and 257 million (251.3%), respectively. It is remarkable that poultry numbers had more than tripled in 29 years from around 102 million to over 359 million. Contrary to these developments, the change for the reporting period of 29 years was less than -0,04% for goats and as much as -88.6% for the swine population. Similarly, other changing percentages observed for categories camels, domestic sheep, buffalo, horses, and mules and asses are -14.9%, -18.1%, -52%, -79%, -86.1%, respectively. The figures also presents a decreasing trend for many livestock species for the reporting period of 1990-2018. Decreasing livestock population numbers of nearly 7.2 million in domestic sheep and around 0.2 million in buffalo have important consequences for the agriculture sector in our country. During the reporting period of 29 years, our country's population is increasingly living in urban areas rather than in rural areas which reduced the demand for some of the animals in small households living in rural areas. Moreover, some animals used for carrying goods previously in rural areas, are not needed any more extensively for this purpose. Thus the demand for some livestock species decreased as result significantly.

**Table 5.6 Livestock population numbers in Turkey, 1990–2018**

(thousand)

| Year | Dairy Cattle | Non-Dairy Cattle | Sheep Domestic | Sheep Merino | Goats | Buffalo | Poultry | Horses | Mules and Asses | Swine | Camels |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 5 893 | 5 485 | 39 711 | 842 | 10 926 | 371 | 102 255 | 513 | 1 187 | 12.0 | 2.0 |
| 1991 | 6 119 | 5 854 | 39 590 | 842 | 10 764 | 366 | 145 051 | 496 | 1 136 | 10.3 | 1.9 |
| 1992 | 6 070 | 5 881 | 38 576 | 840 | 10 454 | 352 | 158 770 | 483 | 1 075 | 11.8 | 1.9 |
| 1993 | 6 032 | 5 878 | 36 709 | 832 | 10 133 | 316 | 184 460 | 450 | 1 013 | 9.0 | 2.0 |
| 1994 | 6 082 | 5 819 | 34 823 | 823 | 9 564 | 305 | 190 033 | 437 | 978 | 8.0 | 2.0 |
| 1995 | 5 886 | 5 903 | 32 985 | 806 | 9 111 | 255 | 135 251 | 415 | 900 | 5.0 | 2.0 |
| 1996 | 5 968 | 5 918 | 32 234 | 838 | 8 951 | 235 | 158 756 | 391 | 843 | 5.0 | 2.0 |
| 1997 | 5 597 | 5 593 | 29 376 | 862 | 8 376 | 194 | 175 223 | 345 | 782 | 4.6 | 1.4 |
| 1998 | 5 489 | 5 542 | 28 560 | 875 | 8 057 | 176 | 243 914 | 330 | 736 | 5.0 | 1.4 |
| 1999 | 5 538 | 5 516 | 29 425 | 831 | 7 774 | 165 | 246 476 | 309 | 680 | 3.4 | 1.4 |
| 2000 | 5 280 | 5 481 | 27 719 | 773 | 7 201 | 146 | 264 451 | 271 | 588 | 3.0 | 1.0 |
| 2001 | 5 086 | 5 462 | 26 213 | 759 | 7 022 | 138 | 223 141 | 271 | 559 | 2.7 | 0.9 |
| 2002 | 4 393 | 5 411 | 24 474 | 700 | 6 780 | 121 | 251 101 | 249 | 512 | 3.6 | 0.9 |
| 2003 | 5 040 | 4 748 | 24 689 | 742 | 6 772 | 113 | 283 674 | 227 | 490 | 7.1 | 0.8 |
| 2004 | 3 876 | 6 194 | 24 438 | 763 | 6 610 | 104 | 302 799 | 212 | 452 | 4.4 | 0.9 |
| 2005 | 3 998 | 6 528 | 24 552 | 752 | 6 517 | 105 | 322 917 | 208 | 423 | 1.9 | 0.8 |
| 2006 | 4 188 | 6 683 | 24 801 | 815 | 6 643 | 101 | 349 402 | 204 | 404 | 1.4 | 1.0 |
| 2007 | 4 229 | 6 807 | 24 491 | 971 | 6 286 | 85 | 273 548 | 189 | 364 | 1.8 | 1.1 |
| 2008 | 4 080 | 6 780 | 22 956 | 1 019 | 5 594 | 86 | 249 044 | 180 | 336 | 1.7 | 1.0 |
| 2009 | 4 133 | 6 591 | 20 722 | 1 028 | 5 128 | 87 | 234 082 | 167 | 286 | 1.9 | 1.0 |
| 2010 | 4 362 | 7 008 | 22 003 | 1 086 | 6 293 | 85 | 238 973 | 155 | 260 | 1.6 | 1.3 |
| 2011 | 4 761 | 7 625 | 23 811 | 1 221 | 7 278 | 98 | 241 499 | 151 | 248 | 1.8 | 1.3 |
| 2012 | 5 431 | 8 484 | 25 893 | 1 533 | 8 357 | 107 | 257 505 | 141 | 236 | 3.0 | 1.3 |
| 2013 | 5 607 | 8 808 | 27 485 | 1 799 | 9 226 | 118 | 270 202 | 136 | 227 | 3.1 | 1.4 |
| 2014 | 5 609 | 8 614 | 29 034 | 2 106 | 10 345 | 122 | 298 030 | 131 | 212 | 2.7 | 1.4 |
| 2015 | 5 536 | 8 458 | 29 302 | 2 206 | 10 416 | 134 | 316 332 | 123 | 198 | 1.6 | 1.5 |
| 2016 | 5 432 | 8 648 | 28 833 | 2 151 | 10 345 | 142 | 333 541 | 120 | 190 | 1.3 | 1.6 |
| 2017 | 5 969 | 9 975 | 31 257 | 2 420 | 10 635 | 161 | 348 144 | 114 | 176 | 1.4 | 1.7 |
| 2018 | 6 338 | 10 705 | 32 513 | 2 682 | 10 922 | 178 | 359 218 | 108 | 165 | 1.6 | 1.7 |

Time series for cattle population with its subcategories in our country are given in Table 5.7. Livestock production can result in $CH_4$ emissions from enteric fermentation and also in $CH_4$ and $N_2O$ emissions from livestock manure management systems. Cattle as a livestock category is a significant source of $CH_4$ in our country because of their large population and high $CH_4$ emission rate due to their ruminant digestive system.

In Turkey there are three dairy cattle types categorized as culture cattle, hybrid cattle and domestic cattle. Culture dairy cattle is a dairy cattle type having higher milk yields compared to domestic dairy cattle whereas milk yields values of hybrid cattle are between them. Hybrid cattle are breeds of culture and domestic dairy cattle. As it is seen in the table, culture dairy cattle population is increasing by years except for the years 1998, 2002 and 2004. But, in general the culture dairy cattle population has a positive trend in the period 1990-2018, which has a percentage increase of 41.3% from 9% in 1990 to 50.3% in 2018 within dairy cattle population. For hybrid cattle population, which was around 2.6 million in 2018 despite being 1.9 million in 1990, a big increase or decrease cannot be observed throughout the same period, though the final two reporting years identified a total increase close to 0.32 million. The share of domestic cattle among dairy cattle was 58.1% in 1990 but this ratio reduced to 9.4% in 2018. Non-dairy cattle number increased by approximately 5.2 million from around 5.5 million in 1990 to more than 10.7 million in 2018 and its share in total number of cattle increased from 48.2% to 62.8% between 1990 and 2018. Furthermore, Figure 5.5 displays three types of dairy cattle as well as non-dairy cattle population numbers for the period of 1990-2018 in a straightforward chart.

**Figure 5.5 Population numbers for cattle categories, 1990–2018**

**Table 5.7 Subcategories of cattle population, 1990–2018**

| Year | Dairy cattle | | | | | | | | Total Non-dairy cattle | | Total Cattle |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Culture | | Hybrid | | Domestic | | Total | | | | |
| | (population) | (%) | (population) | (%) | (population) | (%) | (population) | (%) | (population) | (%) | (population) |
| 1990 | 530 330 | 4.7 | 1 941 170 | 17.1 | 3 421 050 | 30.1 | 5 892 550 | 51.8 | 5 484 507 | 48.2 | 11 377 057 |
| 1991 | 650 738 | 5.4 | 2 087 018 | 17.4 | 3 381 244 | 28.2 | 6 119 000 | 51.1 | 5 853 923 | 48.9 | 11 972 923 |
| 1992 | 698 224 | 5.8 | 2 124 106 | 17.8 | 3 247 848 | 27.2 | 6 070 178 | 50.8 | 5 880 729 | 49.2 | 11 950 907 |
| 1993 | 750 255 | 6.3 | 2 214 723 | 18.6 | 3 066 974 | 25.8 | 6 031 952 | 50.6 | 5 878 048 | 49.4 | 11 910 000 |
| 1994 | 779 689 | 6.6 | 2 308 310 | 19.4 | 2 994 181 | 25.2 | 6 082 180 | 51.1 | 5 818 820 | 48.9 | 11 901 000 |
| 1995 | 870 246 | 7.4 | 2 392 621 | 20.3 | 2 622 719 | 22.2 | 5 885 586 | 49.9 | 5 903 414 | 50.1 | 11 789 000 |
| 1996 | 920 185 | 7.7 | 2 457 925 | 20.7 | 2 590 101 | 21.8 | 5 968 211 | 50.2 | 5 917 789 | 49.8 | 11 886 000 |
| 1997 | 882 093 | 7.9 | 2 355 540 | 21.1 | 2 358 978 | 21.1 | 5 596 611 | 50.0 | 5 593 326 | 50.0 | 11 189 937 |
| 1998 | 879 840 | 8.0 | 2 346 094 | 21.3 | 2 263 114 | 20.5 | 5 489 048 | 49.8 | 5 541 952 | 50.2 | 11 031 000 |
| 1999 | 903 495 | 8.2 | 2 424 626 | 21.9 | 2 209 762 | 20.0 | 5 537 883 | 50.1 | 5 516 117 | 49.9 | 11 054 000 |
| 2000 | 904 850 | 8.4 | 2 335 119 | 21.7 | 2 039 604 | 19.0 | 5 279 573 | 49.1 | 5 481 427 | 50.9 | 10 761 000 |
| 2001 | 912 411 | 8.7 | 2 248 882 | 21.3 | 1 924 526 | 18.2 | 5 085 819 | 48.2 | 5 462 181 | 51.8 | 10 548 000 |
| 2002 | 850 726 | 8.7 | 1 971 743 | 20.1 | 1 570 105 | 16.0 | 4 392 574 | 44.8 | 5 410 924 | 55.2 | 9 803 498 |
| 2003 | 1 034 817 | 10.6 | 2 236 685 | 22.9 | 1 768 868 | 18.1 | 5 040 370 | 51.5 | 4 747 732 | 48.5 | 9 788 102 |
| 2004 | 832 710 | 8.3 | 1 699 803 | 16.9 | 1 343 209 | 13.3 | 3 875 722 | 38.5 | 6 193 624 | 61.5 | 10 069 346 |
| 2005 | 925 613 | 8.8 | 1 717 310 | 16.3 | 1 355 172 | 12.9 | 3 998 095 | 38.0 | 6 528 345 | 62.0 | 10 526 440 |
| 2006 | 1 106 679 | 10.2 | 1 799 411 | 16.6 | 1 281 844 | 11.8 | 4 187 934 | 38.5 | 6 683 430 | 61.5 | 10 871 364 |
| 2007 | 1 299 750 | 11.8 | 1 698 804 | 15.4 | 1 230 888 | 11.2 | 4 229 442 | 38.3 | 6 807 311 | 61.7 | 11 036 753 |
| 2008 | 1 385 727 | 12.8 | 1 665 186 | 15.3 | 1 029 329 | 9.5 | 4 080 242 | 37.6 | 6 779 700 | 62.4 | 10 859 942 |
| 2009 | 1 470 885 | 13.7 | 1 686 064 | 15.7 | 976 201 | 9.1 | 4 133 150 | 38.5 | 6 590 808 | 61.5 | 10 723 958 |
| 2010 | 1 626 416 | 14.3 | 1 787 010 | 15.7 | 948 416 | 8.3 | 4 361 842 | 38.4 | 7 007 958 | 61.6 | 11 369 800 |
| 2011 | 1 868 281 | 15.1 | 1 962 711 | 15.8 | 930 158 | 7.5 | 4 761 150 | 38.4 | 7 625 187 | 61.6 | 12 386 337 |
| 2012 | 2 211 245 | 15.9 | 2 263 400 | 16.3 | 956 758 | 6.9 | 5 431 403 | 39.0 | 8 483 509 | 61.0 | 13 914 912 |
| 2013 | 2 314 282 | 16.1 | 2 395 898 | 16.6 | 897 098 | 6.2 | 5 607 278 | 38.9 | 8 807 979 | 61.1 | 14 415 257 |
| 2014 | 2 427 915 | 17.1 | 2 428 709 | 17.1 | 752 625 | 5.3 | 5 609 249 | 39.4 | 8 613 860 | 60.6 | 14 223 109 |
| 2015 | 2 500 881 | 17.9 | 2 314 063 | 16.5 | 720 835 | 5.2 | 5 535 779 | 39.6 | 8 458 292 | 60.4 | 13 994 071 |
| 2016 | 2 542 164 | 18.1 | 2 235 503 | 15.9 | 654 053 | 4.6 | 5 431 720 | 38.6 | 8 648 435 | 61.4 | 14 080 155 |
| 2017 | 2 940 907 | 18.4 | 2 426 763 | 15.2 | 601 381 | 3.8 | 5 969 051 | 37.4 | 9 974 535 | 62.6 | 15 943 586 |
| 2018 | 3 185 954 | 18.7 | 2 554 949 | 15.0 | 597 003 | 3.5 | 6 337 906 | 37.2 | 10 704 600 | 62.8 | 17 042 506 |

Figures in the table may not add up to the totals due to rounding.

Table 5.3, given previously, presents a detailed perspective on the agriculture sector emissions for the reporting period. GHG emissions from livestock are $CH_4$ in enteric fermentation and $CH_4$ and $N_2O$ in manure management. Rice cultivation leads to $CH_4$ emissions, agricultural soils to $N_2O$ emissions, field burning of crop residues to $CH_4$ and $N_2O$ emissions. Urea application is the only category directly resulting in $CO_2$ emissions reported under the agriculture sector in our country. An overview on emission factors and parameters related to emission calculations from the agriculture sector is given in Annex 3 of the NIR.

### Methane ($CH_4$)

Emissions from enteric fermentation, manure management, rice cultivation and field burning of agricultural residues include methane. The agriculture sector in our country produced 1452.91 kt $CH_4$ (36.3 Mt $CO_2$ eq.) emissions, which equals 56% of agricultural emissions or 63.1% of Turkey's $CH_4$ emissions (without LULUCF), or 7% of Turkey's total emissions in 2018. $CH_4$ emissions had increased by 11 291 kt $CO_2$ eq. (45.1%) from its 1990 level of 25 031 kt $CO_2$ eq. to 36 323 kt $CO_2$ eq. in 2018. This increase is mainly a result of increases of $CH_4$ emissions from enteric fermentation of 9 746 kt $CO_2$ eq., from manure management of 1 534 kt $CO_2$ eq., and from rice cultivation of 152 kt $CO_2$ eq. The total increase as high as 11 291 kt $CO_2$ eq. is responsible for the 59.4% of 19 023 kt $CO_2$ eq. overall increase in emissions from the agricultural sector between 1990 and 2018.

Enteric fermentation is the single dominant category leading to 89.1% in 1990 and 88.3% in 2018 of all $CH_4$ emissions of agriculture sector. Enteric fermentation was followed by manure management with 9.4% in 1990 and 10.7% in 2018. $CH_4$ emissions from field burning of agricultural residues are 1.1% in 1990 and 0.3% in 2018 of all $CH_4$ emissions from the agriculture sector. $CH_4$ emissions share of rice cultivation is 0.4% and 0.7% for 1990 and 2018, respectively.

### Nitrous Oxide ($N_2O$)

Nitrous oxide is a GHG with a high global warming potential. Overall, excluding LULUCF, $N_2O$ emissions accounted for around 7.5% of Turkey's GHG emissions in 2018. Emissions from manure management, agricultural soils, and field burning of agricultural residues include $N_2O$ gas. Agriculture as a sector produced 91.58 kt $N_2O$ emissions (27.3 Mt $CO_2$ eq.), which equals 42.1% of agricultural emissions or 70.1% of Turkey's $N_2O$ emissions (excluding LULUCF) or 5.2% of Turkey's total emissions in 2018. $N_2O$ emissions have increased by 6 934 kt $CO_2$ eq. (34.1%) from 20 358 kt $CO_2$ eq. (1990) to 27 292 kt $CO_2$ eq. (2018).

The source category agricultural soils is the dominant source of $N_2O$ emissions, responsible for 84.5% and 83.2% of total agricultural $N_2O$ emissions for the years 1990 and 2018, respectively. Regarding $N_2O$

emissions, agricultural soils were followed by manure management with 15.1% in 1990 and 16.7% in 2018, and field burning of agricultural residues with 0.4% in 1990 and 0.1% in 2018.

While a percentage as high as 79.3% of the augmentation in nitrous oxide emissions is a result of increases of $N_2O$ emissions in agricultural soils by 5 501 kt $CO_2$ eq., manure management is responsible for the remaining increase of 21.3% with 1477 kt $CO_2$ eq. in $N_2O$ emissions. $N_2O$ emissions of field burning of agricultural residues display a decrease of 53.1% (0.6% of Agricultural $N_2O$ emissions by an amount of 43.5 kt $CO_2$ eq.) between 1990 and 2018. The net increase of 6 934 kt $CO_2$ eq. of $N_2O$ emissions added up to 42.1 % of the overall increase of 19 023 kt $CO_2$ eq. emissions in the agriculture sector between 1990 and 2018.

## 5.2. Enteric Fermentation (Category 3.A)

### Source Category Description:

Enteric fermentation is a digestive process whereby carbohydrates are broken down by micro-organisms into simple molecules. The main product is $CH_4$ gas. Animals produce $CH_4$ during and/or after feed intake. The largest source of $CH_4$ emissions in the agricultural sector in our country is enteric fermentation. It is the biggest source of total carbon equivalent emissions in the agriculture sector with 48.7% (22.3 Mt $CO_2$ eq.) in 1990 and with 49.4% (32 Mt $CO_2$ eq.) in 2018.

In 2018, enteric fermentation contributed as high as 32 060 kt $CO_2$ eq., responsible for nearly half of agricultural emissions as stated above and 6.2% of Turkey's total $CO_2$ eq. emissions. Dairy and non-dairy cattle contributed 25 857 kt $CO_2$ eq. (80.7%) of emissions to the enteric fermentation category and sheep (domestic and merino) contributed 4 500 kt $CO_2$ eq. (14%) of emissions to this category. This source category in 2018 resulted in a value of 9 746 kt $CO_2$ eq. (43.7%) of increased emissions compared to 1990 levels (22 314 kt $CO_2$ eq).

$CH_4$ emissions from enteric fermentation, which are presented by main livestock category sources in Table 5.8, fluctuate over time (also given in Table 5.3). This source category is a key category in terms of methane emissions. Enteric fermentation emissions declined by 24.4% (5.4 Mt $CO_2$ eq.) between 1990 and 2002. The decline in emissions in the early 1990s was primarily occurred by a fall in cattle and sheep numbers; however, the emissions had begun to increase as the numbers of cattle began to rise by late 2004, reflecting changing relative returns to each industry. Due to governmental support, the numbers of many significant livestock species have been increasing in recent years, thereby resulting also in an increase of $CH_4$ emissions for these subcategories. Between 2004 and 2018, emissions from enteric fermentation increased by 69.1% (13.1 Mt $CO_2$ eq).

There have been changes in the relative sources of emissions within enteric fermentation (Table 5.8) since 1990. The largest increase occurred from non-dairy cattle emissions due to increase in its population numbers. In 2018, non-dairy cattle were responsible for 12 843 kt $CO_2$ eq., increased by 6 984 kt $CO_2$ eq. (119%) from the 1990 level of 5 859 kt $CO_2$ eq. Despite a slight increase of 7.6% in dairy cattle population for the period of 1990-2018, this subcategory is responsible for 13 015 kt $CO_2$ eq. in 2018, still an increase of 4 166 kt $CO_2$ eq. (46.6%) above its 1990 level of 8 949 $CO_2$ eq. A closer look at the changes of the composition structure of dairy cattle (culture, hybrid, and domestic cattle) revealed a reasonable explanation for the same period. The dairy cattle population was 5.9 million in total for 1990, which consisted of culture cattle (0.53 million), hybrid cattle (1.94 million), and domestic cattle (3.42 million). The respective figures for the year 2018 were 6.35 million in total for dairy cattle consisting of culture cattle (3.2 million), hybrid cattle (2.55 million), and domestic cattle (0.6 million). The share of culture dairy cattle type had increased significantly in numbers while domestic dairy cattle experienced a reduction both in absolute and relative terms as can be seen in Table 5.7. Population numbers of other animal types for the period 1990-2018 are given in Table 5.6. While Figure 5.6 displays the percentage shares for the subcategories of enteric fermentation emission sources for the latest reporting year, on the next page, Table 5.8 presents $CH_4$ emissions of enteric fermentation regarding livestock categories for the period, 1990-2018.

**Figure 5.6 Enteric Fermentation Emission Sources, 2018**

**Table 5.8 $CH_4$ emissions of enteric fermentation in livestock categories, 1990–2018**

(kt $CO_2$ eq.)

| Year | Dairy Cattle | Non-Dairy Cattle | Sheep Domestic | Sheep Merino | Goats | Buffalo | Horses | Mules & Asses | Swine, Camels | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 8 949 | 5 859 | 4 964 | 137 | 1 366 | 510 | 231 | 297 | 3 | 22 314 |
| 1991 | 9 398 | 6 287 | 4 949 | 137 | 1 346 | 503 | 223 | 284 | 2 | 23 129 |
| 1992 | 9 373 | 6 318 | 4 822 | 137 | 1 307 | 485 | 217 | 269 | 2 | 22 929 |
| 1993 | 9 384 | 6 269 | 4 589 | 135 | 1 267 | 435 | 203 | 253 | 3 | 22 536 |
| 1994 | 9 503 | 6 187 | 4 353 | 134 | 1 196 | 419 | 197 | 245 | 3 | 22 235 |
| 1995 | 9 323 | 6 224 | 4 123 | 131 | 1 139 | 351 | 187 | 225 | 2 | 21 705 |
| 1996 | 9 475 | 6 206 | 4 029 | 136 | 1 119 | 323 | 176 | 211 | 2 | 21 677 |
| 1997 | 8 895 | 5 830 | 3 672 | 140 | 1 047 | 267 | 155 | 196 | 2 | 20 204 |
| 1998 | 8 750 | 5 736 | 3 570 | 142 | 1 007 | 242 | 149 | 184 | 2 | 19 781 |
| 1999 | 8 842 | 5 686 | 3 678 | 135 | 972 | 227 | 139 | 170 | 2 | 19 850 |
| 2000 | 8 484 | 5 678 | 3 465 | 126 | 900 | 201 | 122 | 147 | 1 | 19 124 |
| 2001 | 8 200 | 5 676 | 3 277 | 123 | 878 | 190 | 122 | 140 | 1 | 18 606 |
| 2002 | 7 134 | 5 317 | 3 059 | 114 | 848 | 166 | 112 | 128 | 1 | 16 878 |
| 2003 | 8 464 | 5 565 | 3 086 | 121 | 846 | 156 | 102 | 122 | 1 | 18 464 |
| 2004 | 7 136 | 7 464 | 3 055 | 124 | 826 | 143 | 96 | 113 | 1 | 18 957 |
| 2005 | 7 401 | 7 912 | 3 069 | 122 | 815 | 144 | 94 | 106 | 1 | 19 663 |
| 2006 | 7 862 | 8 073 | 3 100 | 133 | 830 | 138 | 92 | 101 | 1 | 20 331 |
| 2007 | 8 049 | 8 205 | 3 061 | 158 | 786 | 116 | 85 | 91 | 1 | 20 552 |
| 2008 | 7 875 | 8 163 | 2 869 | 166 | 699 | 119 | 81 | 84 | 1 | 20 057 |
| 2009 | 8 032 | 7 879 | 2 590 | 167 | 641 | 120 | 75 | 71 | 1 | 19 576 |
| 2010 | 8 535 | 8 411 | 2 750 | 177 | 787 | 116 | 70 | 65 | 1 | 20 912 |
| 2011 | 9 390 | 9 067 | 2 976 | 198 | 910 | 134 | 68 | 62 | 2 | 22 806 |
| 2012 | 10 779 | 10 158 | 3 237 | 249 | 1 045 | 148 | 64 | 59 | 2 | 25 740 |
| 2013 | 11 169 | 10 519 | 3 436 | 292 | 1 153 | 162 | 61 | 57 | 2 | 26 851 |
| 2014 | 11 271 | 10 277 | 3 629 | 342 | 1 293 | 168 | 59 | 53 | 2 | 27 094 |
| 2015 | 11 182 | 10 092 | 3 663 | 358 | 1 302 | 184 | 55 | 49 | 2 | 26 888 |
| 2016 | 11 029 | 10 349 | 3 604 | 350 | 1 293 | 195 | 54 | 47 | 2 | 26 923 |
| 2017 | 12 221 | 11 869 | 3 907 | 393 | 1 329 | 222 | 51 | 44 | 2 | 30 039 |
| 2018 | 13 015 | 12 843 | 4 064 | 436 | 1 365 | 245 | 49 | 41 | 2 | 32 060 |

Figures in the table may not add up to the totals due to rounding.

### Methodological Issues:

Turkey applies a T1 method to estimate $CH_4$ emissions from enteric fermentation for all livestock populations except cattle for which a T2 method is applied. The T2 method is applied by using mainly country-specific parameters. Necessary data for T2 calculations are mainly gathered from TurkStat Agricultural Statistics Department, Ministry for Agriculture and Forestry, academic sources. The results for cattle in enteric fermentation are presented both in Figure 5.2 and Table 5.8. Moreover, Tables 5.9 and 5.10 present key country-specific parameters regarding T2 calculation; except for methane conversion factor which is a default value given in the 2006 IPCC Guidelines. The annual population for each livestock category is included in Tables 5.6 and 5.7 above. The AD (the population of livestock species) are obtained from TurkStat livestock statistics. TurkStat collects livestock data as explained in the Sector Overview.

Sheep is categorized as merino and domestic sheep in our country. For domestic sheep IPCC default EF for developing countries (5.0 kg $CH_4$ head$^{-1}$ year$^{-1}$) is used. The merino sheep are also a kind of domestic sheep fed for its wool. The weight of merino sheep is higher compared to domestic sheep and their feeding rate is also higher than domestic ones. For these reasons, EF for merino sheep is chosen as a higher value compared to domestic sheep. The EF of merino sheep is taken as an average value (6.5 kg $CH_4$ head$^{-1}$ year$^{-1}$) from the IPCC default EF for developing countries (5.0 kg $CH_4$ head$^{-1}$ year$^{-1}$) and developed countries (8.0 kg $CH_4$/head/year). The country specific typical animal mass values are 50 kg/head and 60 kg/head for domestic sheep and merino sheep, respectively. It is clear that emissions level for merino sheep currently calculated are conservative since the approximate EF for merino sheep is 5.73 kg $CH_4$/head/year obtained by the quotient of the weight figures (60 kg/50kg) raised to the power of 0.75 and then multiplied by the EF for domestic sheep (5.0 kg $CH_4$ head$^{-1}$ year$^{-1}$). As stated clearly in the 2006 IPCC Guidelines (Vol.4, Chapter 10, page 10.24), this approximate figure can only be used to assess the significance of the emissions from a livestock specie. The EF value for merino sheep is clearly higher than the calculated approximate EF value.

### Uncertainties and Time-Series Consistency:

The AD for this sector are gathered from agricultural statistics of TurkStat. Uncertainties for the activity data are determined by TurkStat experts and uncertainty values for EFs are taken from the IPCC Guidelines. The calculated AD uncertainty figure is 8.57% whereas the EF uncertainty value is 12.10% figured out by using Equation 3.2 in the IPCC Guidelines Vol. 1.

| Source category | Gas | Comments on time series consistency |
|---|---|---|
| 3.A | $CH_4$ | All EFs for cattle are not constant over the entire time series because they are estimated mainly according to the split of culture, hybrid and domestic. Since the population numbers for cattle change over the reporting period, the respective EFs also reflect this change. EFs for all other animals types are constant. |

### Source-Specific QA/QC and Verification:

The 2006 IPCC Guidelines are used for the QA/QC procedures of the National GHG emission inventory. The National Inventory System QA/QC Plan prepared by TurkStat is a significant tool for implementing QA/QC procedures for the Inventory. AD for this source category is gathered mainly from the Agricultural Statistics Department of TurkStat. The respective AD used for calculations are published also as official statistics by TurkStat which have their own QA/QC procedures. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculations are re-examined. Moreover, a QA work was conducted by a Project Engineer from CITEPA for this category in January 2020.

### Recalculation:

Recalculations have not occurred in this source category for this reporting year except for rounding errors.

**Table 5.9 Key Tier 2 parameters and estimated emissions for dairy cattle, 1990–2018**

| | Dairy Cattle | | | | | |
|---|---|---|---|---|---|---|
| Year | $CH_4$ Emissions (kt) | Mass (kg) | GE intake (MJ/head/day) | $CH_4$ Conversion rates, $Y_m$ (%) | Milk yield (kg/day) | Digestibility of feed (%) |
| 1990 | 357.9 | 350.4 | 142.5 | 6.50 | 3.70 | 64.19 |
| 1991 | 375.9 | 356.6 | 144.1 | 6.50 | 3.86 | 64.47 |
| 1992 | 374.9 | 360.3 | 144.9 | 6.50 | 3.93 | 64.65 |
| 1993 | 375.4 | 365.3 | 146.0 | 6.50 | 4.04 | 64.92 |
| 1994 | 380.1 | 368.1 | 146.6 | 6.50 | 4.11 | 65.08 |
| 1995 | 372.9 | 377.4 | 148.6 | 6.50 | 4.32 | 65.54 |
| 1996 | 379.0 | 379.9 | 148.9 | 6.50 | 4.35 | 65.66 |
| 1997 | 355.8 | 382.1 | 149.1 | 6.50 | 4.37 | 65.78 |
| 1998 | 350.0 | 383.8 | 149.6 | 6.50 | 4.41 | 65.88 |
| 1999 | 353.7 | 386.1 | 149.8 | 6.50 | 4.44 | 66.01 |
| 2000 | 339.4 | 389.0 | 150.8 | 6.50 | 4.53 | 66.14 |
| 2001 | 328.0 | 391.2 | 151.3 | 6.50 | 4.57 | 66.22 |
| 2002 | 285.3 | 396.2 | 152.4 | 6.50 | 4.67 | 66.43 |
| 2003 | 338.6 | 398.7 | 157.6 | 6.50 | 5.17 | 66.49 |
| 2004 | 285.4 | 400.7 | 172.7 | 6.50 | 6.79 | 66.53 |
| 2005 | 296.0 | 404.1 | 173.7 | 6.50 | 6.87 | 66.61 |
| 2006 | 314.5 | 413.3 | 176.1 | 6.50 | 7.11 | 66.94 |
| 2007 | 322.0 | 421.4 | 178.6 | 6.50 | 7.31 | 67.09 |
| 2008 | 315.0 | 431.4 | 181.1 | 6.50 | 7.56 | 67.48 |
| 2009 | 321.3 | 435.9 | 182.3 | 6.50 | 7.68 | 67.64 |
| 2010 | 341.4 | 440.9 | 183.6 | 6.50 | 7.80 | 67.83 |
| 2011 | 375.6 | 446.8 | 185.0 | 6.50 | 7.94 | 68.05 |
| 2012 | 431.2 | 451.5 | 186.2 | 6.50 | 8.06 | 68.24 |
| 2013 | 446.7 | 454.6 | 186.9 | 6.50 | 8.14 | 68.40 |
| 2014 | 450.8 | 461.0 | 188.5 | 6.50 | 8.30 | 68.66 |
| 2015 | 447.3 | 464.2 | 189.5 | 6.50 | 8.38 | 68.70 |
| 2016 | 441.2 | 467.9 | 190.5 | 6.50 | 8.47 | 68.80 |
| 2017 | 488.8 | 474.1 | 192.1 | 6.50 | 8.61 | 68.99 |
| 2018 | 520.6 | 476.4 | 192.7 | 6.50 | 8.66 | 69.06 |

**Table 5.10 Key Tier 2 parameters and estimated emissions for other cattle, 1990–2018**

| | Other Cattle | | | | |
|---|---|---|---|---|---|
| Year | $CH_4$ Emissions (kt) | Mass (kg) | GE intake (MJ/head/ day) | $CH_4$ Conversion rates, $Y_m$ (%) | Digestibility of feed (%) |
| 1990 | 234.4 | 180.4 | 100.2 | 6.50 | 60.77 |
| 1991 | 251.5 | 185.1 | 100.8 | 6.50 | 61.13 |
| 1992 | 252.7 | 186.6 | 100.8 | 6.50 | 61.27 |
| 1993 | 250.8 | 187.9 | 100.1 | 6.50 | 61.52 |
| 1994 | 247.5 | 189.9 | 99.8 | 6.50 | 61.80 |
| 1995 | 249.0 | 192.1 | 98.9 | 6.50 | 62.08 |
| 1996 | 248.3 | 192.7 | 98.4 | 6.50 | 62.22 |
| 1997 | 233.2 | 191.8 | 97.8 | 6.50 | 62.23 |
| 1998 | 229.4 | 191.5 | 97.1 | 6.50 | 62.29 |
| 1999 | 227.4 | 192.1 | 96.7 | 6.50 | 62.43 |
| 2000 | 227.1 | 194.3 | 97.2 | 6.50 | 62.54 |
| 2001 | 227.0 | 195.6 | 97.5 | 6.50 | 62.60 |
| 2002 | 212.7 | 185.9 | 92.2 | 6.50 | 62.44 |
| 2003 | 222.6 | 228.7 | 110.0 | 6.50 | 63.66 |
| 2004 | 298.5 | 251.8 | 113.1 | 6.50 | 64.43 |
| 2005 | 316.5 | 253.6 | 113.7 | 6.50 | 64.56 |
| 2006 | 322.9 | 258.9 | 113.3 | 6.50 | 64.84 |
| 2007 | 328.2 | 265.0 | 113.1 | 6.50 | 65.02 |
| 2008 | 326.5 | 272.8 | 113.0 | 6.50 | 65.35 |
| 2009 | 315.1 | 274.1 | 112.2 | 6.50 | 65.53 |
| 2010 | 336.5 | 278.8 | 112.6 | 6.50 | 65.84 |
| 2011 | 362.7 | 280.8 | 111.6 | 6.50 | 65.97 |
| 2012 | 406.3 | 287.0 | 112.3 | 6.50 | 66.23 |
| 2013 | 420.8 | 288.6 | 112.1 | 6.50 | 66.33 |
| 2014 | 411.1 | 293.1 | 111.9 | 6.50 | 66.55 |
| 2015 | 403.7 | 296.0 | 112.0 | 6.50 | 66.61 |
| 2016 | 414.0 | 297.2 | 112.3 | 6.50 | 66.72 |
| 2017 | 474.8 | 296.0 | 111.6 | 6.50 | 66.86 |
| 2018 | 513.7 | 299.7 | 112.6 | 6.50 | 66.99 |

### Planned Improvement:

All data and methodologies are kept under review. It is planned to estimate emissions regarding significant livestock categories (i.e. sheep) using the T2 method with respect to the 2006 IPCC Guidelines. Collaboration with various institutions including the MoAF is ongoing in particular on the availability of detailed data on the disaggregation of animals by characteristics such as age, type etc.

## 5.3. Manure Management (Category 3.B)

### Source Category Description:

In Turkey, manure management systems (MMS) distribution data are a result of the combination of various sources, including expert opinions, comparison of countries in the Mediterranean basin, MoAF data, TurkStat data etc. resulting in a country-specific MMS distribution given on Table 5.16.

This source category contains two types of emissions, $CH_4$ and $N_2O$; and for $N_2O$ emissions, the source category is a key category according to both level and trend assessment while for $CH_4$ emissions, the source category is only a key category according to level assessment.

In 2018, emissions including $CH_4$ and $N_2O$ from the manure management category reached 8 443 kt $CO_2$ eq. This number represented 13% of emissions of the agriculture sector. Emissions from this source category in 2018 increased by 3 001 kt $CO_2$ eq., nearly 55.2% above its 1990 level of 5 432 kt $CO_2$ eq. Similarly, the increase is calculated as 1534 kt $CO_2$ eq. for $CH_4$ emissions and 1 477 kt $CO_2$ eq. for $N_2O$ emissions and increasing percentages are 65.2% and 48%, respectively, for the same period, 1990-2018.

Manure management emissions can also be described as direct emissions consisting $CH_4$ and $N_2O$ emissions with a share of 80.6% (6803 kt $CO_2$ eq.) and indirect emissions consisting only of $N_2O$ emissions with a share of 19.4% (1640 kt $CO_2$ eq.). It is also significant to note that there are two types of indirect $N_2O$ emissions to be calculated under manure management, which are due to nitrogen volatilization and nitrogen leaching and run-off. The indirect $N_2O$ emissions share of 19.4% is only a result of amount of manure nitrogen that is lost due to volatilization of $NH_3$ and $NO_x$. Indirect emissions due to leaching and run-off from manure is calculated as 138 kt $CO_2$ eq. for the latest reporting year. This emission level is considered insignificant and reported as NE according to 24/CP.19 Paragraph 37(b). While the following Figure 5.7 presents emission shares of manure management subcategories for the latest reporting year, Table 5.11 combines and presents the emission figures from manure management for the entire reporting period.

**Figure 5.7 Manure Management Emission Sources, 2018**

Regarding MMS, TurkStat has asked academicians for their views on the topic, investigated countries in the Mediterranean Basin whose agriculture sector would resemble Turkey's, searched internally through some of our regional offices, looked for field experiences gained throughout the years within TurkStat and also scrutinized agriculture related data which have not been published so far in order to come up with a distribution that would reflect our country specific conditions better.

**Table 5.11 Overview of emissions from manure management, 1990–2018**

| | | Manure management source category | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Agriculture Total | Total | | $CH_4$ | | Direct $N_2O$ | | Indirect $N_2O$ | |
| Year | (kt $CO_2$ eq.) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) | (kt $CO_2$ eq.) | (%) |
| 1990 | 45 849 | 5 432 | 11.8 | 2 352 | 5.1 | 2 189 | 4.8 | 891 | 1.9 |
| 1991 | 46 727 | 5 660 | 12.1 | 2 440 | 5.2 | 2 251 | 4.8 | 969 | 2.1 |
| 1992 | 46 769 | 5 535 | 11.8 | 2 330 | 5.0 | 2 225 | 4.8 | 979 | 2.1 |
| 1993 | 47 203 | 5 602 | 11.9 | 2 420 | 5.1 | 2 184 | 4.6 | 997 | 2.1 |
| 1994 | 44 717 | 5 799 | 13.0 | 2 661 | 6.0 | 2 141 | 4.8 | 996 | 2.2 |
| 1995 | 43 848 | 5 523 | 12.6 | 2 526 | 5.8 | 2 072 | 4.7 | 925 | 2.1 |
| 1996 | 44 540 | 5 577 | 12.5 | 2 554 | 5.7 | 2 070 | 4.6 | 952 | 2.1 |
| 1997 | 42 266 | 5 161 | 12.2 | 2 308 | 5.5 | 1 932 | 4.6 | 920 | 2.2 |
| 1998 | 43 532 | 5 360 | 12.3 | 2 478 | 5.7 | 1 904 | 4.4 | 978 | 2.2 |
| 1999 | 44 086 | 5 460 | 12.4 | 2 554 | 5.8 | 1 919 | 4.4 | 987 | 2.2 |
| 2000 | 42 138 | 5 151 | 12.2 | 2 334 | 5.5 | 1 837 | 4.4 | 980 | 2.3 |
| 2001 | 39 692 | 5 101 | 12.9 | 2 414 | 6.1 | 1 770 | 4.5 | 917 | 2.3 |
| 2002 | 37 384 | 4 530 | 12.1 | 2 017 | 5.4 | 1 628 | 4.4 | 885 | 2.4 |
| 2003 | 40 529 | 4 957 | 12.2 | 2 230 | 5.5 | 1 749 | 4.3 | 978 | 2.4 |
| 2004 | 41 123 | 4 570 | 11.1 | 1 871 | 4.5 | 1 701 | 4.1 | 999 | 2.4 |
| 2005 | 42 234 | 4 754 | 11.3 | 1 959 | 4.6 | 1 748 | 4.1 | 1 046 | 2.5 |
| 2006 | 43 620 | 4 978 | 11.4 | 2 051 | 4.7 | 1 820 | 4.2 | 1 107 | 2.5 |
| 2007 | 43 179 | 5 047 | 11.7 | 2 183 | 5.1 | 1 822 | 4.2 | 1 042 | 2.4 |
| 2008 | 41 039 | 4 889 | 11.9 | 2 108 | 5.1 | 1 770 | 4.3 | 1 010 | 2.5 |
| 2009 | 41 784 | 4 829 | 11.6 | 2 138 | 5.1 | 1 711 | 4.1 | 980 | 2.3 |
| 2010 | 44 149 | 5 357 | 12.1 | 2 471 | 5.6 | 1 844 | 4.2 | 1 041 | 2.4 |
| 2011 | 46 609 | 5 600 | 12.0 | 2 452 | 5.3 | 2 025 | 4.3 | 1 122 | 2.4 |
| 2012 | 52 332 | 6 383 | 12.2 | 2 837 | 5.4 | 2 288 | 4.4 | 1 258 | 2.4 |
| 2013 | 55 509 | 6 724 | 12.1 | 2 996 | 5.4 | 2 410 | 4.3 | 1 318 | 2.4 |
| 2014 | 55 850 | 7 019 | 12.6 | 3 163 | 5.7 | 2 491 | 4.5 | 1 365 | 2.4 |
| 2015 | 55 761 | 6 905 | 12.4 | 3 031 | 5.4 | 2 493 | 4.5 | 1 381 | 2.5 |
| 2016 | 58 514 | 7 007 | 12.0 | 3 112 | 5.3 | 2 492 | 4.3 | 1 403 | 2.4 |
| 2017 | 62 846 | 7 642 | 12.2 | 3 348 | 5.3 | 2 749 | 4.4 | 1 545 | 2.5 |
| 2018 | 64 872 | 8 443 | 13.0 | 3 886 | 6.0 | 2 917 | 4.5 | 1 640 | 2.5 |

Indirect $N_2O$ emissions from manure management include only emissions due to atmospheric deposition. Manure management indirect $N_2O$ emissions due to leaching and run-off is considered to be insignificant because of its calculated emission level of 138 kt $CO_2$ eq. for the latest reporting year. This level is well-below the threshold level specified in Paragraph 37(b) of 24/CP.19.
Figures in the table may not add up to the totals due to rounding.

### Methane Generation

Livestock manure is primarily composed of organic material and water. Anaerobic and facultative bacteria decompose the organic material under anaerobic conditions. Several biological and chemical factors influence methane generation from manure. The amount of $CH_4$ produced during decomposition is influenced by the climate and the manner in which the manure is managed. The management system determines key factors that affect $CH_4$ production including contact with oxygen, water content, pH, and nutrient availability. Climate factors include temperature and rainfall. Optimal conditions for $CH_4$ production include an anaerobic, water-based environment, a high level of nutrients for bacterial growth, a neutral pH (close to 7.0), warm temperatures, and a moist climate.

Manure management $CH_4$ emissions contributed 3 886 kt $CO_2$ eq. (46% of the manure management category) which constituted 6% of agricultural emissions in 2018 whereas the respective share in 1990 was 5.1%, around 0.9 per cent below the current reporting value.

With respect to all $CH_4$ emissions of the agriculture sector, the second highest $CH_4$ emission source category was manure management for all reporting years with a share value of 9.4% and 10.7% for 1990 and 2018, respectively, and an average share value of 10% for reporting period, 1990-2018.

### Nitrous Oxide Generation

Production of $N_2O$ reported in the manure management category occurs during storage and treatment of manure before it is applied to land.

$N_2O$ emissions contributed 4 557 kt $CO_2$ eq. (54% of the manure management category) which represented 7% of agricultural emissions in 2018 whereas the respective share in 1990 was 6.7%, less than the current percentage of 2018.

With respect to all $N_2O$ emissions of the agriculture sector, the second highest $N_2O$ emission source category was manure management after agricultural soils category for all reporting years. $N_2O$ emissions of manure management accounted for 15.1% and 16.7% of all $N_2O$ emissions in the agriculture sector in 1990 and 2018, respectively.

Direct $N_2O$ emissions from MMS can occur via combined nitrification (under aerobic conditions) and denitrification (an anaerobic process) of nitrogen contained in the manure. The emission of $N_2O$ from manure during storage and treatment depends on the nitrogen and carbon content of manure, on the duration of the storage and type of treatment.

Indirect $N_2O$ emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and $NO_x$. Indirect emissions occur from the deposition of volatilized nitrogen from manure management systems and via runoff and leaching of nitrogen into soils.

The following figure on $CH_4$ and $N_2O$ emissions of manure management and the agriculture sector gives a view on trend inclinations. As indicated above, $CH_4$ and $N_2O$ from manure management are only a fraction of total $CH_4$ and $N_2O$ emissions from the agriculture sector (10.7% and 16.7%, respectively) and therefore these are not a key driver in the overall trends in the agriculture sector. However, the trends for these gases in this category generally reflect the overall trend of the same gases in the agriculture sector. Figure 5.8 displays a trend comparison of these two gas emissions.

**Figure 5.8 Comparing $CH_4$ and $N_2O$ emission trends, 1990–2018**

Typical animal mass values, Nrates and Nitrogen excretion rates (Nex) are crucial parameters in estimating emissions from manure management. Table 5.12 and Table 5.13 present these values for animal categories for the entire reporting period 1990-2018.

## Table 5.12 Typical animal mass, Nrate and Nex values for cattle & poultry, 1990–2018

| | Dairy Cattle | | | Other Cattle | | | Poultry | | |
|---|---|---|---|---|---|---|---|---|---|
| | (mass) | (Nrate)[a] | (Nex)[b] | (mass) | (Nrate)[a] | (Nex)[b] | (mass) | (Nrate)[a] | (Nex)[b] |
| Year | kg | | | kg | | | kg | | |
| 1990 | 350.36 | 0.47 | 60.38 | 180.43 | 0.34 | 22.39 | 2.12 | 0.81 | 0.63 |
| 1991 | 356.58 | 0.47 | 61.47 | 185.11 | 0.34 | 22.97 | 2.08 | 0.82 | 0.62 |
| 1992 | 360.25 | 0.47 | 62.11 | 186.58 | 0.34 | 23.15 | 2.08 | 0.82 | 0.62 |
| 1993 | 365.29 | 0.47 | 62.99 | 187.92 | 0.34 | 23.32 | 2.07 | 0.82 | 0.62 |
| 1994 | 368.09 | 0.47 | 63.49 | 189.92 | 0.34 | 23.57 | 2.07 | 0.82 | 0.62 |
| 1995 | 377.38 | 0.47 | 65.12 | 192.08 | 0.34 | 23.84 | 2.09 | 0.82 | 0.62 |
| 1996 | 379.90 | 0.47 | 65.56 | 192.67 | 0.34 | 23.91 | 2.08 | 0.82 | 0.62 |
| 1997 | 382.13 | 0.47 | 65.95 | 191.79 | 0.34 | 23.80 | 2.11 | 0.81 | 0.63 |
| 1998 | 383.79 | 0.47 | 66.24 | 191.49 | 0.34 | 23.76 | 2.06 | 0.82 | 0.61 |
| 1999 | 386.05 | 0.47 | 66.64 | 192.15 | 0.34 | 23.85 | 2.06 | 0.82 | 0.61 |
| 2000 | 388.99 | 0.47 | 67.15 | 194.31 | 0.34 | 24.11 | 2.05 | 0.82 | 0.61 |
| 2001 | 391.22 | 0.47 | 67.54 | 195.64 | 0.34 | 24.28 | 2.05 | 0.82 | 0.61 |
| 2002 | 396.16 | 0.47 | 68.41 | 185.89 | 0.34 | 23.07 | 2.05 | 0.82 | 0.61 |
| 2003 | 398.71 | 0.47 | 68.85 | 228.67 | 0.34 | 28.38 | 2.05 | 0.82 | 0.61 |
| 2004 | 400.66 | 0.47 | 69.19 | 251.76 | 0.34 | 31.24 | 2.05 | 0.82 | 0.61 |
| 2005 | 404.07 | 0.47 | 69.79 | 253.61 | 0.34 | 31.47 | 2.04 | 0.82 | 0.61 |
| 2006 | 413.27 | 0.47 | 71.40 | 258.90 | 0.34 | 32.13 | 2.03 | 0.82 | 0.61 |
| 2007 | 421.42 | 0.47 | 72.83 | 264.97 | 0.34 | 32.88 | 2.03 | 0.82 | 0.61 |
| 2008 | 431.39 | 0.47 | 74.58 | 272.78 | 0.34 | 33.85 | 2.05 | 0.82 | 0.61 |
| 2009 | 435.92 | 0.47 | 75.37 | 274.12 | 0.34 | 34.02 | 2.04 | 0.82 | 0.61 |
| 2010 | 440.94 | 0.47 | 76.25 | 278.75 | 0.34 | 34.59 | 2.04 | 0.82 | 0.61 |
| 2011 | 446.77 | 0.47 | 77.27 | 280.78 | 0.34 | 34.84 | 2.04 | 0.82 | 0.61 |
| 2012 | 451.53 | 0.47 | 78.10 | 287.04 | 0.34 | 35.62 | 2.04 | 0.82 | 0.61 |
| 2013 | 454.58 | 0.47 | 78.64 | 288.55 | 0.34 | 35.81 | 2.04 | 0.82 | 0.61 |
| 2014 | 461.02 | 0.47 | 79.77 | 293.07 | 0.34 | 36.37 | 2.03 | 0.82 | 0.61 |
| 2015 | 464.23 | 0.47 | 80.33 | 295.96 | 0.34 | 36.73 | 2.03 | 0.82 | 0.61 |
| 2016 | 467.89 | 0.47 | 80.97 | 297.15 | 0.34 | 36.88 | 2.03 | 0.82 | 0.61 |
| 2017 | 474.10 | 0.47 | 82.06 | 295.96 | 0.34 | 36.73 | 2.04 | 0.82 | 0.61 |
| 2018 | 476.42 | 0.47 | 82.47 | 299.67 | 0.34 | 37.19 | 2.04 | 0.82 | 0.61 |

[a] The unit for Nrate is kg N/ (1000 kg animal mass*day).

[b] The unit for Nex is kg N/ (head*yr).

## Table 5.13 Typical animal mass, Nrate and Nex values for some livestock species

| Years | Livestock species | Mass (kg) | Nrate[b] | Nex (kg N/head/yr) |
|---|---|---|---|---|
| 1990 – 2018 | Sheep (domestic) | 50 | 1.17 | 21.35 |
| 1990 – 2018 | Sheep (merino) | 60 | 1.01 | 22.12 |
| 1990 – 2018 | Goats | 45 | 1.37 | 22.50 |
| 1990 – 2018 | Buffalo | 380 | 0.32 | 44.38 |
| 1990 – 2018 | Horses | 238 | 0.46 | 39.96 |
| 1990 – 2018 | Mules & Asses | 130 | 0.46 | 21.83 |
| 1990 – 2018 | Swine[a] | 28 | 0.402 | 4.11 |
| 1990 – 2018 | Camels | 217 | 0.46 | 36.43 |

[a] According to the footnote given on page 10.59, Table 10.19 of the 2006 IPCC Guidelines Vol.4 Chapter 10, nitrogen excretion for swine is based on an estimated country population of 90% market swine and 10% breeding swine. Thus, the Nrate is calculated as given and used in the related Nex calculation: (90%*0.42)+(10%*0.24)=0.402 (Nrate value for swine).

[b] The unit for Nrate is kg N/ (1000 kg animal mass*day).

**Methodological Issues:**

Turkey applies T1 method according to the 2006 IPCC Guidelines to estimate methane and nitrous oxide emissions from manure management for all livestock types. $CH_4$ emissions from manure management are key category according to level assessment.

The annual population for each livestock category is included in Tables 5.6 and 5.7 above. The AD (the population of animals) provider is TurkStat livestock statistics for the entire time series 1990-2018. TurkStat collects livestock data as explained in the Sector Overview. In addition, our country uses the national animal population numbers and allocates the population for each animal subcategory into cool, temperate and warm climate regions in the following manner. First, the animal population numbers are listed according to their respective provinces in our country. Second, all provinces are allocated to one of the three mentioned climate regions concerning their yearly average temperature values. Finally, all population numbers of each animal subcategory within each of the climate regions, namely cool, temperate and warm, are added up before calculating the weighted average with respect to population numbers of the total animal subcategory.

The $CH_4$ EFs are default IPCC T1 factors except for cattle. In Turkey, there are three dairy cattle types categorized as culture cattle, hybrid cattle and domestic cattle. In 2018, the average milk production of culture cattle is around of 3 861 kg head$^{-1}$ yr$^{-1}$. Hence, the EF for culture cattle is taken as the average of EFs of Western Europe and Asia with respect to milk yield of these cattle, and the mean of milk production of Western Europe (6 000 kg head$^{-1}$ yr$^{-1}$) and Asia (1 650 kg head$^{-1}$ yr$^{-1}$) is 3 825 kg head$^{-1}$ yr$^{-1}$. In a similar manner, domestic cattle's EF was taken as Asia EF, and hybrid cattle's EF is taken as the average of culture and domestic cattle EF. The average milk production of domestic cattle is 1 303 kg head$^{-1}$ yr$^{-1}$ and this value is closer to the Asia average milk production value of 1 650 kg head$^{-1}$ yr$^{-1}$. The average milk production of Hybrid cattle is 2 723 kg head$^{-1}$ yr$^{-1}$ and this value is close to the mean of 3 825 and 1 650 kg head$^{-1}$ yr$^{-1}$ which is 2 737 kg head$^{-1}$ yr$^{-1}$. Furthermore, domestic dairy cattle have almost similar properties with Asian cattle like milk yield. Since the T1 method regarding cattle still applies for agricultural categories other than enteric fermentation, the explanation given is still valid for other agricultural categories like manure management.

In order to select appropriate EFs, animal population data, collected from TurkStat databases, are categorized according to their provinces with respective annual temperature figures. $CH_4$ and $N_2O$ emission factors are default 2006 IPCC T1 factors.

The annual average temperatures of the provinces are taken into account in order to select the EFs for manure management. All temperature data are taken directly from the General Directorate of Meteorology. Table 5.14 presents default EFs based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Vol.4 for cattle types and swine for each region according to temperature

classification. Considering annual average air temperature, provinces are categorized between cool (0°C - 14°C) and temperate (15°C - 25°C) climate region. Similar to the methods applied in enteric fermentation, the IPCC default emission factors selected for cattle were based on the IPCC default factors for Western Europe and Asia (see Table 10.14, Vol.4 of the 2006 IPCC Guidelines). The EF for domestic cattle and non-dairy cattle were assumed to be similar with cattle in Asia, because their milk yield values were similar for the former and the weight figures were similar for the latter. The EF for culture cattle was estimated as the mean of the emission factors for dairy cattle from Western Europe and Asia, for the same temperature zone (e.g., at <10° C Turkey estimates that culture cattle have an EF of 15 kg $CH_4$/head/year, which is the average of 21 kg $CH_4$/head/year and 9 kg $CH_4$/head/year from Western Europe and Asia, respectively). The EF for hybrid cattle is the mean of domestic and culture cattle.

For swine, the EFs for Asia from the 2006 IPCC Guidelines (Table 10.14 of Volume 4, Chapter 10) were selected, because of similar body weights.

The EFs for sheep and other livestock, given in the 2006 IPCC Guidelines, are also broken into two climate regions and given in Table 5.15. Turkey does not have a province with an annual average temperature above 25°C; therefore, the warm climate region does not exist in the country.

**Table 5.14 Manure management $CH_4$ emission factors for cattle and swine**

**(kg $CH_4$/head/year)**

| | Cool EF (< 15 °C) | | | | | Temperate EF (15-25 °C) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| **1. Cattle** | | | | | | | | | | | | | | | | |
| Dairy Cattle (Culture) | 15.0 | 16.5 | 17.5 | 19.0 | 20.5 | 23.5 | 25.5 | 27.5 | 29.5 | 32.0 | 34.5 | 37.5 | 40.0 | 43.5 | 47.0 | 50.5 |
| Dairy Cattle (Hybrid) | 12.0 | 13.3 | 13.8 | 15.0 | 16.3 | 18.3 | 19.8 | 21.3 | 22.8 | 24.5 | 26.3 | 28.8 | 30.5 | 33.3 | 35.5 | 38.3 |
| Dairy Cattle (Domestic) | 9 | 10 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 23 | 24 | 26 |
| Non-Dairy Cattle | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **3. Swine** | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 |

**Table 5.15 Manure management $CH_4$ emission factors for sheep and other livestock**

**(kg $CH_4$/head/year)**

| | Cool EF (< 15 °C) | Temperate EF (15-25 °C) |
|---|---|---|
| **2. Sheep** | | |
| Sheep (Domestic) | 0.100 | 0.150 |
| Sheep (Merino) | 0.145 | 0.215 |
| **4. Other livestock** | | |
| Buffalo | 1.00 | 2.00 |
| Camels | 1.28 | 1.92 |
| Goats | 0.11 | 0.17 |
| Horses | 1.09 | 1.64 |
| Mules and asses | 0.60 | 0.90 |
| Poultry | 0.01 | 0.02 |

Furthermore, Table 5.16 presents the Manure Management System (MMS) used according to country-specific values. These updated figures are able to reflect Turkey's conditions in an improved way leading to improved emission estimations with respect to figures used previously in this regard.

**Table 5.16 Manure Management System Distribution, 1990–2018**

(%)

| MS | Anaerobic lagoon | Liquid system | Daily spread | Solid storage | Dry lot | Pasture, range and paddock | Composting | Digesters | Burned for fuel or as waste | Poultry manure |
|---|---|---|---|---|---|---|---|---|---|---|
| Dairy Cattle - Culture | | 10.0 | | 50.0 | 6.0 | 30.0 | | | 4.0 | |
| Dairy Cattle - Hybrid | | 10.0 | | 50.0 | 6.0 | 30.0 | | | 4.0 | |
| Dairy Cattle - Domestic | | 10.0 | | 50.0 | 6.0 | 30.0 | | | 4.0 | |
| Non-Dairy Cattle | | 10.0 | | 50.0 | 6.0 | 30.0 | | | 4.0 | |
| Swine | | | | | | 96.0 | | | 4.0 | |
| Sheep - Domestic | | | | 40.0 | | 60.0 | | | | |
| Sheep - Merino | | | | 40.0 | | 60.0 | | | | |
| Buffalo | | | | 60.0 | 6.0 | 30.0 | | | 4.0 | |
| Camels | | | | 40.0 | | 60.0 | | | | |
| Horses | | | | 25.0 | 15.0 | 60.0 | | | | |
| Goats | | | | 10.0 | 10.0 | 80.0 | | | | |
| Mules and Asses | | | | 25.0 | 15.0 | 60.0 | | | | |
| Chickens | | | | | | 20.0 | | | | 80.0 |
| Ducks & Geese | | | | | | 100.0 | | | | |
| Turkeys | | | | | | 20.0 | | | | 80.0 |

Please note that "Other" given in the CRF Tables relates entirely to poultry manure.

### Uncertainties and Time-Series Consistency:

The approach to produce quantitative uncertainty estimates was used as described in the 2006 IPCC Guidelines for determining uncertainties of that category in total emissions.

The AD for this sector are gathered from agricultural statistics of TurkStat. Uncertainties for activity data are determined by TurkStat experts and uncertainty values for EFs are taken from the IPCC Guidelines. The calculated AD uncertainty figure is 14.1% both for $CH_4$ and $N_2O$ gases whereas EF uncertainty values are 30% and 50% for $CH_4$ and $N_2O$ gases, respectively, as given in the 2006 IPCC Guidelines.

| Source category | Gas | Comments on time series consistency |
|---|---|---|
| 3.B | $CH_4$, $N_2O$ | $CH_4$ EFs are selected according to the yearly mean temperature values of the 81 provinces. $N_2O$ EFs are mainly constant over the entire time series except for cattle (dairy & other) and poultry which reflect the weighted average of their subcategories over the reporting period. |

### Source-Specific QA/QC and Verification:

The 2006 IPCC Guidelines were used for the QA/QC procedures of National GHG emission inventory. A National Inventory System QA/QC Plan prepared by TurkStat is also a significant tool for implementing QA/QC principles for the Inventory. AD for this source category is gathered mainly from the Agricultural Statistics Department of TurkStat. The respective AD, used for calculations, are also published as official statistics by TurkStat which have their own QA/QC procedures. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined. Moreover, a QA work was conducted by a Project Engineer from CITEPA for this category in January 2020.

### Recalculation:

Change of cattle population numbers due to rounding, update in the indirect emission calculations and a revision of the swine manure management systems are the three reasons for the recalculations in the manure management source category. Emission calculations have improved considerably by the latest improvements leading to an increase below 0.02% for manure management with respect to total emissions (without LULUCF) of the country for the reporting year 2017.

### Planned Improvement:

All data and methodologies are kept under review and an upgrade from T1 to T2 will be considered in the future.

## 5.4. Rice Cultivation (Category 3.C)

### Source Category Description:

GHG emissions from rice production are the result of the $CH_4$ gas released by anaerobic digestion of organic substances in the paddy fields. Aforementioned $CH_4$ gas emissions are calculated according to the approach given in the 2006 IPCC Guidelines which are estimated by IPCC's default emission factors. The annual amount of $CH_4$ emitted from a given area of rice is a function of the number and duration of crops grown, water regimes before and during cultivation period, and organic and inorganic soil amendments. Soil type, temperature, fertilizer application, rice cultivar also affects $CH_4$ emissions. $CH_4$ emissions from rice cultivation are not a key category. Figure 5.9 presents total annual harvested area in hectare (line drawn in blue - left axis) and total $CH_4$ emissions emitted in kt (line drawn in dark red - right axis) for rice cultivation covering the period 1990-2018.

**Figure 5.9 Harvested area and emitted $CH_4$ for rice cultivation, 1990–2018**

Rice cultivation contributed 10.09 kt $CH_4$ (252 kt $CO_2$ eq.) emissions or 0.39% of total agricultural emissions in 2018 whereas the respected value for the year 1990 was around 4 kt $CH_4$ (100 kt $CO_2$ eq.) emissions or 0.22% of total sector emissions.

Overall, emissions from rice cultivation increased by 152.2 kt $CO_2$ eq. (152%) for the entire reporting period and the increase was calculated around 24% between the years 2011 and 2018.

Table 5.17, given below, presents the activity data and estimated emissions of this source category in detail.

**Table 5.17 Irrigated area and estimated emissions for rice cultivation, 1990–2018**

| | Total | | Continuously Flooded | | Intermittently Flooded | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Single Aeration | | Multiple Aeration | |
| Year | (kt $CO_2$ eq.) | Area (ha) | (kt $CO_2$ eq.) | Area (ha) | (kt $CO_2$ eq.) | Area (ha) | (kt $CO_2$ eq.) | Area (ha) |
| 1990 | 100.19 | 46 348 | 51.84 | 17 276 | 16.30 | 8 800 | 32.05 | 20 272 |
| 1991 | 99.85 | 40 400 | 59.98 | 16 800 | 14.52 | 7 811 | 25.36 | 15 789 |
| 1992 | 94.11 | 42 978 | 48.68 | 16 351 | 15.86 | 8 117 | 29.57 | 18 510 |
| 1993 | 101.50 | 44 842 | 56.31 | 18 751 | 17.79 | 8 988 | 27.40 | 17 103 |
| 1994 | 89.71 | 39 562 | 48.48 | 15 950 | 16.65 | 8 321 | 24.58 | 15 291 |
| 1995 | 112.60 | 49 955 | 62.85 | 21 203 | 16.80 | 8 479 | 32.95 | 20 273 |
| 1996 | 125.73 | 54 779 | 75.58 | 25 859 | 16.65 | 8 403 | 33.50 | 20 517 |
| 1997 | 124.25 | 54 995 | 73.35 | 25 447 | 17.28 | 8 902 | 33.62 | 20 646 |
| 1998 | 135.19 | 59 885 | 79.51 | 27 566 | 19.34 | 10 035 | 36.34 | 22 284 |
| 1999 | 146.65 | 64 983 | 87.09 | 30 133 | 20.97 | 10 984 | 38.59 | 23 866 |
| 2000 | 128.04 | 57 859 | 71.20 | 24 800 | 20.45 | 10 706 | 36.39 | 22 353 |
| 2001 | 131.99 | 59 000 | 75.04 | 26 085 | 25.72 | 13 770 | 31.23 | 19 145 |
| 2002 | 134.89 | 59 809 | 78.18 | 27 055 | 24.74 | 13 171 | 31.98 | 19 583 |
| 2003 | 142.91 | 65 000 | 77.70 | 26 697 | 27.45 | 14 757 | 37.76 | 23 546 |
| 2004 | 156.16 | 69 990 | 88.66 | 30 326 | 28.53 | 15 409 | 38.97 | 24 255 |
| 2005 | 183.46 | 84 909 | 96.05 | 32 926 | 38.01 | 20 662 | 49.40 | 31 321 |
| 2006 | 212.06 | 99 043 | 108.95 | 37 559 | 42.50 | 23 211 | 60.62 | 38 273 |
| 2007 | 202.87 | 93 799 | 110.05 | 37 841 | 36.79 | 20 965 | 56.03 | 34 994 |
| 2008 | 215.89 | 99 493 | 116.96 | 40 325 | 41.44 | 23 338 | 57.49 | 35 830 |
| 2009 | 208.73 | 96 444 | 110.30 | 38 116 | 41.44 | 22 996 | 56.99 | 35 332 |
| 2010 | 202.13 | 98 966 | 86.23 | 29 856 | 40.92 | 22 554 | 74.98 | 46 557 |
| 2011 | 204.33 | 99 383 | 93.73 | 32 456 | 40.30 | 22 235 | 70.30 | 44 692 |
| 2012 | 249.03 | 119 664 | 120.32 | 41 613 | 44.94 | 25 027 | 83.77 | 53 024 |
| 2013 | 230.66 | 110 592 | 111.64 | 38 670 | 42.21 | 23 458 | 76.81 | 48 465 |
| 2014 | 229.54 | 108 649 | 114.59 | 39 628 | 46.26 | 26 015 | 68.69 | 43 006 |
| 2015 | 239.99 | 115 856 | 115.71 | 40 057 | 42.45 | 23 865 | 81.83 | 51 934 |
| 2016 | 242.97 | 116 056 | 120.66 | 41 763 | 43.62 | 24 390 | 78.69 | 49 904 |
| 2017 | 233.76 | 109 505 | 121.81 | 42 153 | 43.20 | 24 128 | 68.75 | 43 225 |
| 2018 | 252.37 | 120 137 | 125.12 | 42 178 | 46.70 | 26 106 | 80.55 | 50 853 |

Figures in the table may not add up to the totals due to rounding.

### Methodological Issues:

Harvested area data for rice cultivation are taken from TurkStat agricultural statistics and area records are available for all districts of Turkey since 1990. T1 method is used for calculation, and the emission factor and scaling factors are taken from the 2006 IPCC Guidelines. The cultivation period of rice production in Turkey is around 130 days. The methods used in our country includes continuously flooded, intermittently flooded with single aeration and intermittently flooded with multiple aeration. Accordingly, disaggregated case parameters are used for these methods from the 2006 IPCC Guidelines. Initially, the required data are gathered from TurkStat's regional offices. With reference to these data, values of scaling factors according to the 2006 IPCC Guidelines are determined for both $SF_w$ and $SF_p$ parameters. Due to the large geographical diversity of our country, all values for disaggregated scaling factors are used. Moreover, information on cultivation period for rice production is also obtained from regional offices of TurkStat and all different periods are taken into account. The default $CH_4$ baseline emission factor ($EF_c$) applied is 1.30 $CH_4$/ha/day for rice cultivation emission calculations, a non-key category, under T1 method. Organic amendments are not used or, if any, used in negligible amounts. This, in turn, reduces the value of the related scaling factor ($SF_o$) to 1, a multiplicative identity, given by the Equation 5.3 on page 5.50 of the 2006 IPCC Guidelines Vol.4. Furthermore, scaling factors ($SF_{s,r}$) for other related variables are not available, and as a result not used, which is in line with the information provided on page 5.48 presented in the 2006 IPCC Guidelines Vol.4. Accordingly, emissions from this source category are calculated and reported taking into account the country's conditions.

### Uncertainties and Time-Series Consistency:

The AD for this sector are gathered from agricultural statistics of TurkStat, and the information about water regime, water regime prior to rice cultivation and cultivation periods, that are crucial in determining appropriate scaling factors, are obtained from regional offices of TurkStat for all provinces and their districts in Turkey. The AD for this sector are gathered from agricultural statistics of TurkStat and the related AD uncertainty figure is considered to be 5%. Uncertainty value for the EF is calculated as 76.74% according to the information given in the 2006 IPCC Guidelines.

An Approach 2 uncertainty analysis using the Monte Carlo technique was carried out on the methodology used to estimate emissions of methane from rice cultivation category. The Monte Carlo uncertainty range for $CH_4$ emissions from rice cultivation is similar to Approach 1, the error propagation method and mean estimates of combined MC simulation uncertainty lie within a range of -68.98% to +70.43% in 2017. For more detailed information about Monte Carlo method, please refer to the uncertainty section in the annexes.

| Source category | Gas | Comments on time series consistency |
|---|---|---|
| 3.C | $CH_4$ | EFs reflect the subcategories of the methods applied for rice cultivation. The calculations reflect different type of water regimes applied in the country. A list of EFs and related parameters used for emission calculations are listed in Annex 3 of the National Inventory Report. |

### Source-Specific QA/QC and Verification:

The 2006 IPCC Guidelines were used for the QA/QC procedures of National GHG emission inventory. A National Inventory System QA/QC Plan prepared by TurkStat is also a significant tool for implementing QA/QC principles for the Inventory. AD for this source category is mainly gathered from the Agricultural Statistics Department of TurkStat. The respective AD, used for calculations, are also published as official statistics by TurkStat which have their own QA/QC procedures. Emission trends are analyzed. Moreover, a QA work was conducted by a Project Engineer from CITEPA for this category in January 2020.

### Recalculation:

There was no recalculation exercised regarding emission estimates from this source category in this submission.

### Planned Improvement:

All data and methodologies are kept under review. There are no further planned improvements in this source category.

## 5.5. Agricultural Soils (Category 3.D)

### Source Category Description:

This source, which is a key category, contains $N_2O$ emissions from synthetic fertilizers, organic fertilizers and crop residues. In this section $N_2O$ emissions from pasture, range and paddock manure, cultivation of organic soils, and indirect emissions, which consist of atmospheric deposition and nitrogen leaching and run-off, are estimated too. The complete time series regarding emissions are submitted in this submission. Both direct and indirect $N_2O$ emissions from this source category are key categories according to the trend assessment while only direct $N_2O$ emissions are key category according to the level assessment (with and without LULUCF).

Agriculture soils produced 76.2 kt $N_2O$ (22.7 Mt $CO_2$ eq.) emissions in 2018 and agriculture soils is the largest source category of $N_2O$ emissions in Turkey. This figure represented 83.2% of $N_2O$ emissions in the Agriculture sector, around 58% of Turkey's $N_2O$ emissions (without LULUCF), and 35% of agricultural emissions. Emissions were 5 001 kt $CO_2$ eq. (32%) above the 1990 level of 17 196 kt $CO_2$ eq. in the year 2018. Direct $N_2O$ emissions increased by 5 056 kt $CO_2$ eq. (33.6%) whereas indirect $N_2O$ emissions increased by 436 kt $CO_2$ eq. (20.5%) for the given period 1990-2018. The increase is a result of the emission changes of direct and indirect $N_2O$ emissions from managed soils. The total change of direct $N_2O$ emissions is a result of increases in the subcategories inorganic N fertilizers, a subcategory of organic N fertilizers, urine and dung deposited by grazing animals, crop residues, and also decreases in cultivation of organic soils and two subcategories of organic N fertilizers. Direct $N_2O$ emissions due to mineralization/immobilization related to loss/gain of soil organic carbon in the agriculture sector did not occur for the entire reporting period.

Several subcategories contribute to emissions from agricultural soils from direct and indirect pathways (Table 5.18, Table 5.19, Table 5.20 and Table 5.21). Direct $N_2O$ emissions occur directly from the soils to which N has been added or released; indirect emissions arise from volatilization (evaporation or sublimation) and subsequent redeposition of $NH_3$ or $NO_x$, or result from leaching and runoff of soil N within water (IPCC, 2006). A precise overview is also given in Figure 5.10 and Table 5.18 for direct and indirect $N_2O$ emissions. The abbreviations used in Figure 5.10 are listed on the headings of Table 5.19 and 5.21.

**Figure 5.10 Sub-categories of Agricultural Soils Emission Sources, 2018**

**Table 5.18 Overview of $N_2O$ emissions from managed soils, 1990–2018**

| Year | Agriculture Total (kt $CO_2$ eq.) | Agricultural soils: Total (kt $CO_2$ eq.) | Total (%) | Direct $N_2O$ (kt $CO_2$ eq.) | Direct $N_2O$ (%) | Indirect $N_2O$ (kt $CO_2$ eq.) | Indirect $N_2O$ (%) |
|---|---|---|---|---|---|---|---|
| 1990 | 45 849 | 17 196 | 37.5 | 15 070 | 32.9 | 2 126 | 4.6 |
| 1991 | 46 727 | 17 043 | 36.5 | 14 936 | 32.0 | 2 107 | 4.5 |
| 1992 | 46 769 | 17 411 | 37.2 | 15 273 | 32.7 | 2 138 | 4.6 |
| 1993 | 47 203 | 17 969 | 38.1 | 15 799 | 33.5 | 2 170 | 4.6 |
| 1994 | 44 717 | 15 821 | 35.4 | 13 869 | 31.0 | 1 952 | 4.4 |
| 1995 | 43 848 | 15 750 | 35.9 | 13 842 | 31.6 | 1 909 | 4.4 |
| 1996 | 44 540 | 16 282 | 36.6 | 14 330 | 32.2 | 1 952 | 4.4 |
| 1997 | 42 266 | 15 898 | 37.6 | 14 022 | 33.2 | 1 876 | 4.4 |
| 1998 | 43 532 | 17 216 | 39.5 | 15 226 | 35.0 | 1 990 | 4.6 |
| 1999 | 44 086 | 17 553 | 39.8 | 15 505 | 35.2 | 2 048 | 4.6 |
| 2000 | 42 138 | 16 777 | 39.8 | 14 840 | 35.2 | 1 938 | 4.6 |
| 2001 | 39 692 | 15 008 | 37.8 | 13 257 | 33.4 | 1 751 | 4.4 |
| 2002 | 37 384 | 14 986 | 40.1 | 13 271 | 35.5 | 1 715 | 4.6 |
| 2003 | 40 529 | 16 074 | 39.7 | 14 229 | 35.1 | 1 845 | 4.6 |
| 2004 | 41 123 | 16 449 | 40.0 | 14 608 | 35.5 | 1 841 | 4.5 |
| 2005 | 42 234 | 16 718 | 39.6 | 14 853 | 35.2 | 1 866 | 4.4 |
| 2006 | 43 620 | 17 213 | 39.5 | 15 293 | 35.1 | 1 920 | 4.4 |
| 2007 | 43 179 | 16 555 | 38.3 | 14 690 | 34.0 | 1 865 | 4.3 |
| 2008 | 41 039 | 15 054 | 36.7 | 13 357 | 32.5 | 1 697 | 4.1 |
| 2009 | 41 784 | 16 289 | 39.0 | 14 505 | 34.7 | 1 785 | 4.3 |
| 2010 | 44 149 | 16 814 | 38.1 | 14 982 | 33.9 | 1 832 | 4.1 |
| 2011 | 46 609 | 17 208 | 36.9 | 15 316 | 32.9 | 1 892 | 4.1 |
| 2012 | 52 332 | 19 097 | 36.5 | 16 973 | 32.4 | 2 124 | 4.1 |
| 2013 | 55 509 | 20 656 | 37.2 | 18 369 | 33.1 | 2 287 | 4.1 |
| 2014 | 55 850 | 20 504 | 36.7 | 18 193 | 32.6 | 2 311 | 4.1 |
| 2015 | 55 761 | 20 744 | 37.2 | 18 423 | 33.0 | 2 321 | 4.2 |
| 2016 | 58 514 | 22 880 | 39.1 | 20 350 | 34.8 | 2 530 | 4.3 |
| 2017 | 62 846 | 23 316 | 37.1 | 20 717 | 33.0 | 2 599 | 4.1 |
| 2018 | 64 872 | 22 697 | 35.0 | 20 135 | 31.0 | 2 562 | 3.9 |

Figures in the table may not add up to the totals due to rounding.

**Table 5.19 Categories of Direct $N_2O$ emissions of agricultural soils, 1990–2018**

(kt $CO_2$ eq.)

| Year | Total $N_2O$ Emissions from Managed Soils | Direct $N_2O$ Emissions from Managed Soils | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Total | Inorganic N Fertilizers ($F_{SN}$) | Organic N Fertilizers ($F_{ON}$) | Urine and Dung Deposited by Grazing Animals ($F_{PRP}$) | Crop Residues ($F_{CR}$) | Loss/ Gain of soil organic matter ($F_{SOM}$) | Culti-vation of Organic Soils ($F_{OS}$) |
| 1990 | 17 196 | 15 070 | 5 618 | 2 770 | 5 015 | 1 585 | NO | 82 |
| 1991 | 17 043 | 14 936 | 5 169 | 2 870 | 5 128 | 1 687 | NO | 82 |
| 1992 | 17 411 | 15 273 | 5 649 | 2 846 | 5 059 | 1 638 | NO | 82 |
| 1993 | 17 969 | 15 799 | 6 253 | 2 805 | 4 946 | 1 713 | NO | 82 |
| 1994 | 15 821 | 13 869 | 4 714 | 2 747 | 4 804 | 1 523 | NO | 82 |
| 1995 | 15 750 | 13 842 | 4 934 | 2 609 | 4 581 | 1 635 | NO | 82 |
| 1996 | 16 282 | 14 330 | 5 373 | 2 620 | 4 565 | 1 689 | NO | 82 |
| 1997 | 15 898 | 14 022 | 5 465 | 2 468 | 4 275 | 1 732 | NO | 82 |
| 1998 | 17 216 | 15 226 | 6 532 | 2 493 | 4 245 | 1 874 | NO | 82 |
| 1999 | 17 553 | 15 505 | 6 957 | 2 526 | 4 280 | 1 660 | NO | 82 |
| 2000 | 16 777 | 14 840 | 6 456 | 2 440 | 4 091 | 1 771 | NO | 82 |
| 2001 | 15 008 | 13 257 | 5 304 | 2 316 | 3 903 | 1 653 | NO | 82 |
| 2002 | 14 986 | 13 271 | 5 615 | 2 167 | 3 655 | 1 752 | NO | 82 |
| 2003 | 16 074 | 14 229 | 6 279 | 2 332 | 3 861 | 1 674 | NO | 82 |
| 2004 | 16 449 | 14 608 | 6 400 | 2 279 | 3 793 | 2 055 | NO | 82 |
| 2005 | 16 718 | 14 853 | 6 427 | 2 338 | 3 873 | 2 134 | NO | 82 |
| 2006 | 17 213 | 15 293 | 6 587 | 2 426 | 4 009 | 2 189 | NO | 82 |
| 2007 | 16 555 | 14 690 | 6 349 | 2 366 | 3 930 | 1 964 | NO | 82 |
| 2008 | 15 054 | 13 357 | 5 306 | 2 278 | 3 759 | 1 933 | NO | 82 |
| 2009 | 16 289 | 14 505 | 6 621 | 2 179 | 3 568 | 2 055 | NO | 82 |
| 2010 | 16 814 | 14 982 | 6 292 | 2 323 | 3 858 | 2 427 | NO | 82 |
| 2011 | 17 208 | 15 316 | 5 897 | 2 523 | 4 225 | 2 589 | NO | 82 |
| 2012 | 19 097 | 16 973 | 6 706 | 2 822 | 4 738 | 2 625 | NO | 82 |
| 2013 | 20 656 | 18 369 | 7 419 | 2 972 | 5 023 | 2 874 | NO | 82 |
| 2014 | 20 504 | 18 193 | 6 991 | 3 088 | 5 274 | 2 759 | NO | 82 |
| 2015 | 20 744 | 18 423 | 6 961 | 3 109 | 5 306 | 2 965 | NO | 82 |
| 2016 | 22 880 | 20 350 | 8 881 | 3 113 | 5 299 | 2 976 | NO | 82 |
| 2017 | 23 316 | 20 717 | 8 264 | 3 419 | 5 778 | 3 175 | NO | 82 |
| 2018 | 22 697 | 20 135 | 7 153 | 3 614 | 6 090 | 3 195 | NO | 82 |

$F_{SOM}$ refers to Mineralization/ Immobilization associated with loss/gain of soil organic matter.
Figures in the table may not add up to the totals due to rounding.

**Table 5.20 Subcategories of Organic N fertilizers emissions, 1990–2018**
**(kt $CO_2$ eq.)**

| Year | Total $N_2O$ Emissions from Managed Soils | Total Direct $N_2O$ Emissions from Managed Soils | Organic N Fertilizers ($F_{ON}$) | Organic N Fertilizers ($F_{ON}$) | | |
|---|---|---|---|---|---|---|
| | | | | Animal Manure Applied to Soils | Sewage Sludge Applied to Soils | Other Organic Fertilizers Applied to Soils |
| 1990 | 17 196 | 15 070 | 2 770 | 2 766 | 3 | 1 |
| 1991 | 17 043 | 14 936 | 2 870 | 2 866 | 3 | 1 |
| 1992 | 17 411 | 15 273 | 2 846 | 2 842 | 3 | 1 |
| 1993 | 17 969 | 15 799 | 2 805 | 2 800 | 3 | 1 |
| 1994 | 15 821 | 13 869 | 2 747 | 2 743 | 3 | 1 |
| 1995 | 15 750 | 13 842 | 2 609 | 2 605 | 3 | 1 |
| 1996 | 16 282 | 14 330 | 2 620 | 2 616 | 3 | 1 |
| 1997 | 15 898 | 14 022 | 2 468 | 2 459 | 8 | 1 |
| 1998 | 17 216 | 15 226 | 2 493 | 2 480 | 12 | 1 |
| 1999 | 17 553 | 15 505 | 2 526 | 2 513 | 12 | 2 |
| 2000 | 16 777 | 14 840 | 2 440 | 2 427 | 12 | 2 |
| 2001 | 15 008 | 13 257 | 2 316 | 2 303 | 11 | 2 |
| 2002 | 14 986 | 13 271 | 2 167 | 2 159 | 6 | 2 |
| 2003 | 16 074 | 14 229 | 2 332 | 2 309 | 22 | 1 |
| 2004 | 16 449 | 14 608 | 2 279 | 2 258 | 20 | 1 |
| 2005 | 16 718 | 14 853 | 2 338 | 2 325 | 11 | 1 |
| 2006 | 17 213 | 15 293 | 2 426 | 2 422 | 3 | 1 |
| 2007 | 16 555 | 14 690 | 2 366 | 2 360 | 4 | 2 |
| 2008 | 15 054 | 13 357 | 2 278 | 2 271 | 4 | 2 |
| 2009 | 16 289 | 14 505 | 2 179 | 2 174 | 4 | 1 |
| 2010 | 16 814 | 14 982 | 2 323 | 2 319 | 3 | 1 |
| 2011 | 17 208 | 15 316 | 2 523 | 2 519 | 3 | 1 |
| 2012 | 19 097 | 16 973 | 2 822 | 2 818 | 3 | 1 |
| 2013 | 20 656 | 18 369 | 2 972 | 2 968 | 3 | 1 |
| 2014 | 20 504 | 18 193 | 3 088 | 3 084 | 2 | 1 |
| 2015 | 20 744 | 18 423 | 3 109 | 3 105 | 2 | 1 |
| 2016 | 22 880 | 20 350 | 3 113 | 3 110 | 2 | 1 |
| 2017 | 23 316 | 20 717 | 3 419 | 3 415 | 2 | 1 |
| 2018 | 22 697 | 20 135 | 3 614 | 3 610 | 2 | 2 |

Other organic fertilizers applied to soils consist only of compost applied to soils.
Figures in the table may not add up to the totals due to rounding.

**Table 5.21 Categories of Indirect $N_2O$ emissions of agricultural soils, 1990–2018**

(kt $CO_2$ eq.)

| | | Indirect $N_2O$ Emissions from Managed Soils | | |
|---|---|---|---|---|
| Year | Total $N_2O$ Emissions from Managed Soils | Total | Atmospheric Deposition $N_2O_{(ATD)}$ | Nitrogen Leaching and Run-off $N_2O_{(L)}$ |
| 1990 | 17 196 | 2 126 | 1 966 | 160 |
| 1991 | 17 043 | 2 107 | 1 950 | 158 |
| 1992 | 17 411 | 2 138 | 1 977 | 161 |
| 1993 | 17 969 | 2 170 | 2 003 | 167 |
| 1994 | 15 821 | 1 952 | 1 807 | 145 |
| 1995 | 15 750 | 1 909 | 1 763 | 145 |
| 1996 | 16 282 | 1 952 | 1 802 | 151 |
| 1997 | 15 898 | 1 876 | 1 729 | 147 |
| 1998 | 17 216 | 1 990 | 1 829 | 161 |
| 1999 | 17 553 | 2 048 | 1 884 | 164 |
| 2000 | 16 777 | 1 938 | 1 781 | 156 |
| 2001 | 15 008 | 1 751 | 1 612 | 139 |
| 2002 | 14 986 | 1 715 | 1 575 | 140 |
| 2003 | 16 074 | 1 845 | 1 696 | 150 |
| 2004 | 16 449 | 1 841 | 1 687 | 154 |
| 2005 | 16 718 | 1 866 | 1 709 | 156 |
| 2006 | 17 213 | 1 920 | 1 759 | 161 |
| 2007 | 16 555 | 1 865 | 1 711 | 154 |
| 2008 | 15 054 | 1 697 | 1 557 | 139 |
| 2009 | 16 289 | 1 785 | 1 632 | 152 |
| 2010 | 16 814 | 1 832 | 1 675 | 157 |
| 2011 | 17 208 | 1 892 | 1 732 | 160 |
| 2012 | 19 097 | 2 124 | 1 947 | 177 |
| 2013 | 20 656 | 2 287 | 2 095 | 192 |
| 2014 | 20 504 | 2 311 | 2 121 | 190 |
| 2015 | 20 744 | 2 321 | 2 128 | 192 |
| 2016 | 22 880 | 2 530 | 2 317 | 214 |
| 2017 | 23 316 | 2 599 | 2 383 | 216 |
| 2018 | 22 697 | 2 562 | 2 353 | 209 |

Figures in the table may not add up to the totals due to rounding.

Direct $N_2O$ emissions from agricultural soils are a result of addition of nitrogen in the form of: inorganic nitrogen fertilizers, organic nitrogen fertilizers (predominantly in the form of animal manure), inputs from above-ground and below-ground crop residues and from forages during pasture renewal, mineralization of cropland soil organic matter loss, urine and dung deposited by grazing animals, and cultivation of organic soils. These combined direct $N_2O$ soil emissions contributed 20 135 kt $CO_2$ eq. (88.7%) to emissions from the Agricultural soils category and around 31% of emissions under the total Agriculture sector in 2018. This is an increase of 5 065 kt $CO_2$ eq. (33.6%) from the 1990 reported figure of 15 070 kt $CO_2$ eq.

A major direct source of $N_2O$ emissions from agricultural soils is an outcome of the use of synthetic fertilizer. Around a third (30.3%) of increase in direct emissions from agricultural soils, observed between 1990 and 2018, is a result of an increase in synthetic fertilizers application. Widespread increase in the use of such nitrogen-based fertilizers has been driven by the need for greater crop yields and more intensive farming practices. In 2018, $N_2O$ emissions from synthetic nitrogen fertilizers contributed 7 153 kt $CO_2$ eq. (31.5%) to emissions from the managed soils category. This is an increase of 1 536 kt $CO_2$ eq. (27.3%) from the 1990 level of 5 618 kt $CO_2$ eq. Nitrogen emissions of synthetic fertilizer contributed 11% to the total emissions under the agriculture sector for the latest reported year.

In 2018, $N_2O$ emissions from organic N fertilizers contributed 3 614 kt $CO_2$ eq. (15.9%) to emissions from the agricultural soils category and 5.6% of emissions under the total agriculture sector. Activity data (as dry matter) for sewage sludge and compost are both received within TurkStat. The country-specific nitrogen content value for sewage sludge is taken as 5.15% calculated as an average according to the values given in a specific research study (Topaç and Başkaya, 2008), while the nitrogen content for compost is taken as 1%. The only source of emissions due to other organic fertilizers is compost because there is neither activity data available on possibly other organic fertilizers except compost data nor an indication of such an activity.

An increase of 844 kt $CO_2$ eq. (30.5%) is observed from the 1990 level of 2 770 kt $CO_2$ eq. of $N_2O$ emissions due to organic nitrogen fertilisers of which sewage sludge applied to soils marks a slightly peculiar trend observable on Table 5.20. Since Turkey applied the Tier 1 methodology, emissions are directly linked to change of activity data. In the initial years, the number of municipal wastewater treatment plants increased in our country leading to an increase of emissions thereof. Thereafter, three factors could be given which resulted in a reduction of these emissions: First, increase in number of landfilling sites affected the trend in sewage sludge applied to soils. Second, new legislations which set criteria on sewage sludge for its use on agricultural soils limited the use of sewage sludge on soils. Third, some wastewater treatment plants using sewage sludge extensively before, changed their treatment methods.

As observed from Table 5.19, $N_2O$ emissions from urine and dung deposited by grazing animals contributed 6 090 kt $CO_2$ eq. (26.8%) to emissions from the agricultural soils category and 9.4% of emissions under the total agriculture sector. This is an increase of 1 075 kt $CO_2$ eq. (21.2%) from the 1990 level of 5 015 kt $CO_2$ eq. Moreover, $N_2O$ emissions from crop residues contributed 3 195 kt $CO_2$ eq. (14.1%) to emissions from the agricultural soils category and 4.9% of emissions under the total agriculture sector. This is a value of more than twofold presenting an increase of 1 610 kt $CO_2$ eq. (101.6%) from the 1990 level of 1 585 kt $CO_2$ eq.

Emission calculations from cultivation of organic soils are directly based on related LULUCF sector data given in CRF Tables 4.B and 4.C while the related activity data source is the new LULUCF reporting system (LRS) in Turkey for which further information is given in the sector overview section of the LULUCF sector.

Indirect $N_2O$ emissions were calculated as 2 562 kt $CO_2$ eq. for 2018. Indirect $N_2O$ emissions through atmospheric deposition contributed 2 353 kt $CO_2$ eq. (10.4%) to emissions from the agricultural soils category and 3.6% of emissions under the total agriculture sector in 2018. This is an increase of 387 kt $CO_2$ eq. (19.7%) from the 1990 level of 1 966 kt $CO_2$ eq. Indirect $N_2O$ emissions through leaching and runoff added 209 kt $CO_2$ eq. (0.9%) to emissions from the agricultural soils category in 2018 and 0.3% of emissions under the total agriculture sector.

Briefly, agricultural soils emissions have increased by 32% (around 5.5 Mt $CO_2$ eq.) between 1990 and 2018. The increase is a result of the emission changes of direct and indirect $N_2O$ emissions from managed soils. The former, direct $N_2O$ emissions increased by around 5.1 Mt $CO_2$ eq. and the latter, indirect $N_2O$ emissions, by 0.4 Mt $CO_2$ eq. for the given period, 1990-2018. The total net increase of 5.1 Mt $CO_2$ eq. of direct $N_2O$ emissions is a result of changes in inorganic N fertilizers, organic N fertilizers, urine and dung deposited by grazing animals, crop residues subcategories. The related figures of changes for 1990-2018 concerning these five subcategories mentioned are 1 536 kt (27.3%), 844 kt (30.5%), 1 075 kt (21.4%), and 1 610 kt (101.6%), respectively. Estimations from cultivation of organic soils are constant 82 kt $CO_2$ eq. Organic N fertilizers are further subdivided into three groups, namely animal manure, sewage sludge, and other organic fertilizers (which consists entirely of compost), all applied to soils. Increase in animal manure applied to soils is 844 kt (30.5%) from 2 766 kt to 3 610 kt whereas the two other organic N fertilizer subcategories decreased as given in Table 5.20. On the other hand, the total increase of 0.4 Mt $CO_2$ eq. of indirect $N_2O$ emissions is divided into two categories, atmospheric deposition and nitrogen leaching and run-off. The related figures of changes for these subcategories are 387 kt (19.7%) and 49 kt (30.3%) for the period of 1990-2018, respectively.

### Methodological Issues:

$N_2O$ emissions are calculated by using the IPCC T1 approach. The AD used in emission calculation are taken from agricultural statistics of TurkStat. The $N_2O$ EFs are IPCC T1 default factors.

When a crop is harvested, a portion of the crop is left in the field to decompose. The remaining plant matter is a nitrogen source that undergoes nitrification and denitrification and can thus contribute to $N_2O$ production. Crop residue emission calculations follow the principles given in the 2006 IPCC Guidelines. $N_2O$ emissions are now calculated according to all cultivated plants in Turkey. Both aboveground and belowground crop residues are included. Crop yields vary from year to year, as well as cultivated areas, which cause fluctuations in crop residue emissions. It should be further added that the default EF used for crop residues is 0.01 (kg $N_2O$–N)/(kg N) except for the EF used for flooded rice which is 0.003 (kg $N_2O$–N)/(kg N). This difference in EFs used in calculations for crop residues emissions is the reason which leads to inconstant implied emission factors over the reporting period. The following table summarizes the crop headings for which $N_2O$ emissions due to crop residues are calculated in our country.

**Table 5.22 Crop data used for crop residue calculations**

| Major Crop Types | Individual Crops | |
|---|---|---|
| Grains | Maize | Sorghum |
| Beans & Pulses | Wheat | Soybean |
| Tubers | Rice | Dry bean |
| Root crops, other | Barley | Potato |
| N-fixing forages | Oats | Peanut |
| Non-N-fixing forages | Millet | Alfalfa |
| Grass-clover mixtures | Rye | |

| Source category | Gas | Comments on time series consistency |
|---|---|---|
| 3.D.1 | $N_2O$ | All EFs are constant over the entire time series for $F_{SN}$, $F_{OS}$ and all sub-categories of $F_{ON}$ . The same EF for $F_{CR}$ is used except for flooded rice and the EF for $F_{PRP}$ is chosen according to the livestock species. |

$N_2O$ emissions are calculated by using the IPCC T1 approach. The AD used in emission calculation are taken from agricultural statistics of TurkStat. The $N_2O$ EFs are IPCC T1 default factors.

In the 2016 Assessment Review Report of Turkey published on 24 April 2017, a recommendation was made by the Expert Review Team to investigate the actual leaching conditions in Turkey and estimate the most likely $Frac_{LEACH-(H)}$ for its national conditions and include justification of the $Frac_{LEACH-(H)}$ value used in its NIR. The ERT also noted that taking into account the dry conditions in Turkey and the use

of a $Frac_{LEACH-(H)}$ of 0.3, a likely overestimation is taking place. To address this recommendation and use a more precise $Frac_{LEACH-(H)}$ value this issue was evaluated. As a result, a revised country-specific $Frac_{LEACH-(H)}$ value of 0.015 is calculated and used with respect to the footnote of Table 11.3 given in the 2006 IPCC Guidelines Volume 4. While calculating this parameter, following steps are implemented: First, the Climate Map (Figure 5.11) was used as a reference data source while keeping in mind that in this data source, the entire 12 months in a year (including also the dry months of June, July and August) are taken into account, not 9 months as mentioned in the footnote of Table 11.3 given in the 2006 IPCC Guidelines Vol.4. Secondly, soil water-holding capacity is assumed to be zero as a conservative approach. In other words, if rainfall exceeds the potential evapotranspiration then it is assumed that surface runoff or leaching occurs. In general conditions there is a soil layer (shallow or deep) that hold water and disable surface runoff but it is not possible to make an assessment on the water capacity of soils for the whole country. Thirdly, it is assumed that leaching/run-off occurs in all wet areas shown in the Climate Map but not occur at the dry areas of the country. Thus, a ratio between wet and dry areas has been determined and multiplied by 0.3 to result in 0.015 as a $Frac_{LEACH-(H)}$ value. This newly calculated value has been used since the submission of the 1990-2016 Inventory.

According to the 2006 IPCC Guidelines, a climate map of Turkey (Figure 5.11) was prepared before and this map was used to estimate a country-specific $Frac_{LEACH-(H)}$ value. Four sub-climate types have been identified based on 2006 IPCC Guidelines that use basic climatic parameters of temperature, potential evapotranspiration and precipitation. The Climate map given below is taken from the IPCC Climate Zones which is also presented as Figure 3A.5.1 on page 3.38 of the 2006 IPCC Guidelines Volume 4.

**Figure 5.11 Climate Map of Turkey**

Regarding emission calculations from crop residues, TurkStat received country specific data on renewal fractions and fractions removed from the MoAF. Renewal fraction for a yearly crop is 1 by definition of 1/X (where X is 1 year). This figure is used for most of the crops given in the classification of Table 11.2 on pages 11.17-11.18 of the 2006 IPCC Guidelines Vol. 4 (since almost all crops are yearly crops). A fraction of 0.25 (as a result of 1/X where X is 4 years) was used only for the following major crop types and individual crops according to the information received from the Ministry of Agriculture and Forestry: perennial grasses, grass-clover mixtures, alfalfa.

Fraction removed values are given for all major crop types and individual crops as received from the Ministry of Agriculture and Forestry as follows: first for major crop types: grains (0.75), beans & pulses (0.80), tubers (0.00), root crops and other (0.00), N-fixing forages (0.80), non-N-fixing forages (1.00), perennial grasses (0.90), grass-clover mixtures (0.90); and second for Individual crop types: alfalfa (0.90), maize, milllet, soya bean and dry bean (0.80), wheat, rice, barley, oats, sorghum and rye (0.75), peanuts (0.70); potato (0.00). The use of these data set helped in order to reflect the country specific conditions in an improved way. It should be further noted that default values given in Table 11.2 of the 2006 IPCC Guidelines Vol.4 were used to calculate emissions from crop residues according to the T1 method.

### Uncertainties and Time-Series Consistency:

The AD for this sector are gathered from agricultural statistics of TurkStat except the data on synthetic fertilizer consumption amounts, which is obtained from the MoAF. By using Equation 3.2 in the 2006 IPCC Guidelines Vol. 1, uncertainties for the AD are calculated as 19.56% by TurkStat for $N_2O$ Emissions from Managed Soils. In a similar manner, the respective EF uncertainty for this category is figured out as 93.89% after taking the default uncertainties in the 2006 IPCC Guidelines into consideration.

### Source-Specific QA/QC and Verification:

The 2006 IPCC Guidelines are used for the QA/QC procedures of the National GHG emissions inventory. A National Inventory System QA/QC Plan prepared by TurkStat is also a significant tool for implementing QA/QC principles for the Inventory. AD for this source category is gathered mainly from the Agricultural Statistics Department of TurkStat. Data used for calculations are published also as official statistics by TurkStat which have their own QA/QC procedures. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined.

It should be further noted that the activity data for synthetic fertilizer is also almost entirely consistent with the data available on International Fertilizer Association's (IFA) website. Moreover, a QA work was conducted by a Project Engineer from CITEPA for this category in January 2020.

**Recalculation:**

Mainly the addition of default Nbedding values, updating Fsew and Fcomp calculations by adding N % contents to the calculations, rounding of cattle population numbers, the use of country-specific MMS distribution for swine, revision/update in crop residues activity data (only for the year 2017) are the reasons for the increase in agricultural soils category. Moreover, changes in direct emissions from the agricultural soils category have implications on the emissions from the indirect sources of the same category as well.

For this source category, the recalculation has an increasing effect of 0.046% and 0.038% for the year 1990 and 2017, respectively, and the average recalculation ratio for the period of 1990-2017 is calculated as 0.036%. Our country-specific conditions are better reflected after this improvement accomplished while the recalculation affected all reported years of last year's submission.

**Planned Improvement:**

All data and methodologies are kept under review and further possible improvements are being considered for the future. The results on improving estimations of manure management emissions will be also useful to improve emission estimations from agricultural soils in the future.

## 5.6. Prescribed Burning of Savannas (Category 3.E)

This source category of agriculture emission is not relevant to Turkey.

## 5.7. Field Burning of Agricultural Residues (Category 3.F)

### Source Category Description:

The burning of residual crop material releases $CH_4$, $N_2O$, CO, $NO_x$ and NMVOC emissions of which CO, $NO_x$ and NMVOC are indirect greenhouse gases. The resulting atmospheric release of agricultural residues is not considered to be a net carbon dioxide source, as carbon is being absorbed again during the growing season. This source category is not a key category. Emission values due to field burning of crop residues are given in Table 5.3 for all twenty-nine reporting years. After consultations with the Ministry of Forestry and Agriculture (MoAF) and our own research, wheat, barley, maize and rice cultivation areas in Turkey were found to be included in field burning. As field burning is illegal and widely under control, it is becoming rare. Also, the machinery is usually able to manage the excess straw left on fields after harvesting. As given in detail in Table 5.23, $CH_4$ and $N_2O$ emissions contributed 124 kt $CO_2$ eq. and 38 kt $CO_2$ eq., respectively to this source category in 2018.

**Table 5.23 Field burning of agricultural residues emissions, 1990 and 2018**

| | Emissions (kt $CO_2$ eq.) | | | | Changes from 1990 to 2018 | | Percentages of agricultural sector (%) | |
|---|---|---|---|---|---|---|---|---|
| **Category** | 1990 | (%) | 2018 | (%) | (kt $CO_2$ eq.) | (%) | 1990 | 2018 |
| **Field burning of agricultural residues** | 347 | 100 | 163 | 100 | -184 | -53.1 | 0.76 | 0.25 |
| **$CH_4$** | 265 | 76 | 124 | 76 | -141 | -53.1 | 0.58 | 0.19 |
| **$N_2O$** | 82 | 24 | 38 | 24 | -44 | -53.1 | 0.18 | 0.06 |

Figures in the table may not add up to the totals due to rounding.

In 2018, field burning of agricultural residues contributed 163 kt $CO_2$ eq. This emission value represented 0.25% of all agricultural emissions. Total field burning $CO_2$ eq. emissions presented a decreasing trend because of prohibitive legislative measures undertaken. $CH_4$ and $N_2O$ emissions from field burning have mostly a negative trend except for some years. Prohibiting measures and increase of public awareness related to field burning are key in this decreasing trend and relevant authorities impose also fines on misconduct. Additionally, the use of advanced agricultural machinery assisting farmers in handling crop residues more easily, could also be considered as another factor leading to the reduction of field burning practices. The respective percentage change from this source category is -53.1% for the period of 1990-2018.

### Methodological Issues:

Activity data used in the emission estimation are taken from TurkStat agricultural statistics. The emissions are calculated according to the 2006 IPCC Guidelines, Volume 4, Equation 2.27 given in Chapter 2. Crop residue per hectare is multiplied with area of both cereal and then with fraction burned, combustion factor and the related emission factor. Both $CO_2$ and $N_2O$ emissions are calculated using the IPCC Tier 1 approach. The values calculated for $CH_4$ and $N_2O$ emissions were converted to their $CO_2$ equivalents by multiplying the values with their respective global warming potential factors. Other emission values under this source category, $NO_x$, CO, and NMVOC, are not estimated. Most of the farmers obey the rules, prohibiting stubble burning leaving some farmers still practicing crop residue burning.

### Uncertainties and Time-Series Consistency:

The AD for this sector was gathered from agricultural statistics of TurkStat. Uncertainty values concerning AD for two GHG sources under this source category, namely $CH_4$ and $N_2O$, are each estimated to be 50% whereas uncertainty values concerning EF for these gases are estimated to be 40% as recommended in the 2006 IPCC Guidelines.

| Source category | Gas | Comments on time series consistency |
|---|---|---|
| 3.F | $CH_4$, $N_2O$ | All EFs are constant over the entire time series |

### Source-Specific QA/QC and Verification:

The 2006 IPCC Guidelines are used for the QA/QC procedures of National GHG emission inventory in order to attain quality objectives. A National Inventory System QA/QC Plan prepared by TurkStat is also a significant tool for implementing QA/QC principles for the Inventory. AD for this source category is gathered mainly from the Agricultural Statistics Department of TurkStat. Data used for calculations are also published as official statistics by TurkStat which have their own QA/QC procedures. Calculations are implemented every year during preparation phase of the NIR. If errors or inconsistencies are found, they are documented and corrected accordingly. Regarding field burning of agricultural residues, a more representative data for burned fraction were received from MoAF. Annual checks are undertaken whether new scientific articles for updating emission factors have been published in Turkey. Moreover, a QA work was conducted by a Project Engineer from CITEPA for this category in January 2020.

**Recalculation:**

There was no recalculation exercised regarding emission estimates from this source category in this submission.

**Planned Improvement:**

All data and methodologies are kept under review and there are no further planned improvements regarding this source.

## 5.8. Liming (Category 3.G)

Possible data sources are considered for this mandatory category. Three factors are possibly more important than others which explain the use of carbonate limestone applied to soils in our country. First, soils with lower pH values are present mainly in the Black Sea Region and Marmara Region. Second, it is not an inexpensive method to reduce acidity of soils for agricultural producers by using carbonate limestone. Third, there are also non-carbon containing materials available, which are suitable to be applied on soils in order to reduce acidity. Our research is almost decisive in estimating $CO_2$ emissions amounted to far less than 100 kt for 2015 due to liming applied on soils. Hence, this category is considered as insignificant according to 24/CP.19, annex I, paragraph 37(b). This source category is reported as not estimated in the CRF.

## 5.9. Urea Application (Category 3.H)

### Source Category Description:

Adding urea to soils for fertilization leads to reduction of the $CO_2$ gas that was fixed during the industrial production process. Urea ($CO(NH_2)_2$) transforms to ($NH_4^+$), hydroxyl ion ($OH^-$) and bicarbonate ($HCO_3^-$) with the presence of urease and water. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into $CO_2$ and water.

$CO_2$ emissions from applied urea led to emissions as high as 1257.5 kt $CO_2$ in 2018. This is an amount representing 1.9% of agricultural emissions. Emissions from the urea application in 2018 were 798 kt $CO_2$ (173.4%) above its 1990 level of 460 kt $CO_2$. This source category, $CO_2$ emissions from urea application, is not a key category.

The observed recent increase (except in 2018) in the use of urea application is a result of its use as a substitute for nitrogen based fertilizers. Turkey has limited the use of nitrogen based fertilizers since June 2016 leading to a shift in farmers' preferences.

Emissions values due to urea application are given in Table 5.3 for the period of 1990-2018 in the sector overview section. Figure 5.12 presents yearly amount of urea application in kt (line drawn in blue - left axis) and $CO_2$ emissions emitted in kt (line drawn in dark red - right axis). A direct relationship between the two values is observed on the figure. In addition, a slowly increasing trend can be seen on the figure except for the last three reporting years. The latest year clearly presents a decrease while the years before, 2016 and 2017, indicate big increases.

**Figure 5.12 Urea application and emitted $CO_2$, 1990–2018**

### Methodological Issues:

Emissions associated with the application of urea are calculated by using T1 approach (equation 11.13; IPCC, 2006), using the default EF for carbon conversion of 0.20. This value equals the carbon content of atomic weight of urea. In order to calculate $CO_2$-C emissions resulting from urea application, the annual total amount of urea applied to the soils in the country is determined. Related AD, required for the calculation are taken from the website of MoAF under the title of "Chemical fertilizer production, consumption, import and export statistics" which is updated every year for the subsequent year. The data time series starts from the year 1981 and our country uses directly the consumption data presented as the related activity data which is accessible on the following link: https://www.tarimorman.gov.tr/Konular/Bitkisel-Uretim/Bitki-Besleme-ve-Tarimsal-Teknolojiler/Bitki-Besleme-Istatistikleri# .

### Uncertainties and Time-Series Consistency:

Under the IPCC (2006) T1 methodologies, the default EFs are used, which assume conservatively that all carbon in the urea is emitted as $CO_2$ into the atmosphere. The default EF is assumed to be certain under this theoretical assumption.

A default 10% uncertainty is applied regarding the AD used in the emission calculation of urea application, whereas the uncertainty of the EF is taken as 50% as given in the IPCC Guidelines under the related section.

An uncertainty analysis using the Monte Carlo technique was carried out to estimate emissions of $CO_2$ from urea application in this inventory year. Combined uncertainty in $CO_2$ emissions in 2017 is estimated at -13.54% to +14.70%. The Monte Carlo uncertainty range for $CO_2$ emissions from urea application is lower than Approach 1 results and the main reason of this difference is explained in Annex 2.

### Source-Specific QA/QC and Verification:

The 2006 IPCC Guidelines are used for the QA/QC procedures of the National GHG emission inventory. A National Inventory System QA/QC Plan, prepared by TurkStat, is a significant tool for implementing QA/QC principles for the Inventory. AD for this source category is obtained from the MoAF. Data used for calculations are a part of official statistics, which have their own QA/QC procedures. Specially, the time series was checked for consistency. As a general QC check, the multiplications of activity data and emission factor were double checked for $CO_2$ emissions from urea application. Emission trends are analyzed. If there is a high fluctuation in the series, then AD and emission calculation are re-examined. It should be further noted that the activity data for urea applied is almost entirely consistent with the data available on the website of the International Fertilizer Industry Association (IFA). Moreover, a QA work was conducted by a Project Engineer from CITEPA for this category in January 2020.

### Recalculation:

There was no recalculation exercised regarding emission estimates from this source category in this submission.

### Planned Improvement:

All data and methodologies are kept under review. There are no further planned improvements in this source category.

## 5.10. Other Carbon-Containing Fertilizers (Category 3.I)

This category cannot be estimated because of insufficient AD.

## 5.11. Other (Category 3.J)

There are no other activities to be considered under this sector.

# 6. LULUCF (CRF SECTOR 4)

## 6.1. Sector Overview

The LULUCF sector of Turkey is a net removal dominated by forests. The 22.8 Mha of forest area removed a net 84.8 Mt of $CO_2$ eq. from the atmosphere in 2018. Other land uses were net emissions while accounting less than 1 percent of forest land removals. The net removal of the sector when HWP was added has been 94.7 Mt of $CO_2$ eq. representing a 69.4 percent increase compared to 1990. The reason of the increase was increased productivity of the forests reflected by increment values.

**Figure 6.1 The trend of LULUCF sector net removals including HWP, 1990-2018**

The LULUCF sector methodologies related to activity data have entirely been modified with the support of EU funded project entitled "Technical Assistance for Developed Analytical Basis for Land Use, Land Use Change and Forestry (LULUCF) Sector" started in August 2017. The project completed in July 2019 but so far provided significant improvements on;

i. Developing spatially explicit land use matrices for the land uses and conversions starting from 1990,

ii. Capacity building in relevant inventory agencies,

iii. Development of a Program of Works, Annual Work Plan and Compendium,

iv. A new system to calculate and report GHG emissions/removals in LULUCF sector,

v. Activity data disaggregated into 8 Ecoregions and 28 Forest Administrative regions for higher level accuracy,

vi. Updated NIR.

The details of the project can be seen at the project web page https://www.lulucf-tr.org/

The new LULUCF reporting system (LRS) of Turkey is composed of below elements:

- A spatially explicit land cover driven AD produced by an experienced international company. The system uses tracks all land cover with satellite images since 1990 and detects all changes on an annual basis. Each 1 hectare unit of land (1 ha) is tracked for the reporting period and calculated for emissions and removals on a consistent approach
- Updated land use definitions
- A new system of reporting that is capable of performing calculations; harmonize spatial data with EF data, archiving, and tools to enhance QA/QC
- Re-assessed EFs by a team of experts
- An EF database and Reference Library developed and used. The system enables experts to update the EFs and coefficients on a continuous basis
- A database has been developed to query all land covers and changes. Thus, land cover data base on Satellite images can be checked and verified anytime

The LRS is managed and used by a group of national experts for different elements. This means that the inventory is prepared by more than 10 experts each focus on a different item. This enables sharing of responsibility and improvement potential.

The new system increased the transparency significantly by using AD produced by an international remote sensing company, and a renewed NIR. Furthermore, the new spatially explicit land use tracking system improved completeness, accuracy and consistency because the same methodology has been used for the whole reporting period and for all land uses with around 90 percent accuracy. The new reporting system caused significant changes in emissions and removals. The main categories of removals have been FL-FL and HWPs. The outcome of the key category analysis for 2018 was listed in Table 6.1.

**Table 6.1 Key categories identification in the LULUCF sector (Tier 1)**

| | CATEGORIES OF EMISSIONS AND REMOVALS | Gas | 2018 |
|---|---|---|---|
| 4.A.1 | Forest Land Remaining Forest Land | $CO_2$ | Key (L,T) |
| 4.G | Harvested Wood Products | $CO_2$ | Key (L,T) |

Within the new reporting system, a national EF database together with a reference library have been established. They are very similar with the IPCC EF database in structure and includes all data used in the inventory even the default coefficients.

The context and management of the EF database is as follows;

Emission factors are the second set of data, needed for estimation of GHG emissions and removals. An emission factor (EF) is defined as the average emission rate of a given GHG for a given source, relative to units of activity (IPCC 1996). Emission factors can be collected from various sources, from national and international statistics and monitoring, databases, research studies, scientific papers, technical reports etc. The use of appropriate emission factor is essential as wrong selection may lead to under- or overestimation of emissions and removals. In general, the IPCC guidelines include a large list of emission factors, which can be used when Tier 1 methods are selected for estimation. Moreover, there exists emission factor database (EFDB: https://www.ipcc-nggip.iges.or.jp/EFDB/main.php) of the IPCC, which also includes large set of emission factors, relevant for the LULUCF.

The following approach is implemented for updating the national EF database:

- Check for improvement of EF database on annual basis (e.g. new EF gathered, higher Tier method selected, category become key source etc.).
- Collect country-specific emission and stock change factors for all key categories.
- Collect all relevant default emission factors of the IPCC for other categories (non-key).
- Assign appropriate specific emission and stock change factors to each corresponding category.
- Add and update EF database when new or improved emission factors are obtained or determined, respectively.
- Store a reference of the EF in the archive (data source, uncertainty, background data etc.).
- Record the person and reason whenever your update the EF database.

The EF database is embedded in the reporting system on the main computer and has the below table format;

| EF ID | GAS | DESCRIPTION | PRACTICES | CONDITIONS | REGION | VALUE | STD DEV | RANGE | on Coeff (%) | UNIT | REFERENCE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil | | | | | | | | | | | |
| 1 | CO2 | Soil C Stock | native broadleaved forest | grazed forests and shrubs, not | Southeast Anatolia Dec | 44.33 | 12.23 | 33.64-64.00 | 27.58 | T/ha | BUDAK, M., GÜNAL, H., 2018. Yukarı Dicle |
| 2 | CO2 | soil organic ca | Mature and young fir stands and adjacent pasture and agriculture sites | The study area consists of a variation of broadleaf and conifer stands with ages between 40 and 150 year homogenous soils | Mature and Young Fir Stands- Pasture and Agriculture Sites in Kastamonu Northwest Region | Forest (mature fir) 47.4 Forest (young fir) 48.6 | Forest (mature fir) ±13.4 SOC Forest (young fir) ±13.9 SOC | | the descriptive statistics table is not available | T/ha | Temel SARIYILDIZ (Kastamonu University, Faculty of Forestry, 37100 Kastamonu / Turkey) , Gamze SAVACI (Kastamonu University, Faculty of Forestry, 37100 Kastamonu / Turkey) , Züleyha MARAL (Kastamonu University, Faculty of Forestry, 37100 Kastamonu / Turkey) |
| 3 | N | total nitrogen | Mature and young fir stands and adjacent pasture and agriculture sites | The study area consists of a variation of broadleaf and conifer stands with ages between 40 and 150 year homogenous soils | Mature and Young Fir Stands- Pasture and Agriculture Sites in Kastamonu Northwest Region | Forest (mature fir) 4.45 Forest (young fir) 5.61 | Forest (mature fir) ±0.48 STN Forest (young fir) ±0.88 STN | | the descriptive statistics table is not available | T/ha | Temel SARIYILDIZ (Kastamonu University, Faculty of Forestry, 37100 Kastamonu / Turkey) , Gamze SAVACI (Kastamonu University, Faculty of Forestry, 37100 Kastamonu / Turkey) , Züleyha MARAL (Kastamonu University, Faculty of Forestry, 37100 Kastamonu / Turkey) |

### Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

The Land Use definitions of Turkey have been updated with the new land monitoring system. The country has been divided into 8 ecological zones based on international and national literature. The ecoregions assessment has provided the possibility to disaggregate calculations into more homogenous regions and use of more specific EFs and coefficients. The Eco zones identified by Serengil (2018) and relationship with climate types are given below (Figure 6.2. and Table 6.2.)

**Figure 6.2 The ecoregions in Turkey (Serengil, 2018)**

**Table 6.2 Ecozones in Turkey and their relationships with climate classifications (Serengil, 2018)**

| | Ecozone | Biome | Climate Type | IPCC Climate Type |
|---|---|---|---|---|
| 1 | Euxine-Colchic deciduous forest | Temperate deciduous & mixed forest | Black Sea Coastal Zone | Warm Temp Moist |
| 2 | North Anatolian deciduous, coniferous and mixed forest | Temperate deciduous, coniferous and mixed forest | Black Sea Inland Temperate Climate Zone | Warm Temp Dry |
| 3 | Mediterranean coastal zone deciduous and coniferous forest | Mediterranean forest, shrubs | Mediterranean Coastal Zone | Warm Temperate Moist-Dry |
| 4 | Mediterranean Mountain zone | Mediterranean forest, shrubs | Mediterranean Inland Temperate Mountain Climate | Warm Temp Dry |
| 5 | Aegean Inland deciduous and coniferous forest | Mediterranean forest, shrubs | Mediterranean Inland Temperate Climate | Warm Temp Dry |
| 6 | Central Anatolian steppe | Temperate deciduous & mixed forest | Semi Dry Steppe Climate | Warm-Cool Temp Dry |
| 7 | East Anatolian deciduous forest zone | Temperate deciduous & mixed forest | Temperate Continental Climate | Warm Temp Dry |
| 8 | East Anatolian steppe | Temperate grassland, shrubs and steppe | Continental Mountainous Climate | Cool Temp Moist-Dry |

The new definitions of land uses have been explained below. The former forest definition in 2018 submission was the national legal definition. The national definition had a threshold just for the minimum area which is 3 ha. The application of the new definition and spatially explicit land tracking system did not change the forest area drastically but the share of productive forest in forest land category increased. The difference between the old and the new systems has been discussed in Forest land category below.

**Forest Land:** Forest Land category has been disaggregated into 2 major subcategories;

Productive Forest: Tree and woodland communities more than 1 ha with a crown closure over 10 percent, which are grown by both human efforts and naturally are regarded as Forest.

Other Wooded Forest (OWF): The same definition applies except the crown closure. The crown closure for OWF is between 1 to 10 percent. The wooded land with crown closures less than 1 percent are allocated under grassland.

**Cropland:** The following land uses are included in the croplands.

- Arable land (Non-irrigated arable land, Permanently irrigated land)
- Permanent crops (Vineyards, Fruit trees and berry plantations, Olive groves)
- Poplar plantations in or near the agriculture area

**Grassland:** All woody/herbaceous vegetation is defined as grassland. The grasslands include shrubs and trees that provide a crown closure of less than 1 percent. The demand for grazing areas is high in the country and a differentiation between managed and unmanaged is not technically possible thus all grasslands are accepted as managed.

**Wetlands:** This category is divided into two as managed and unmanaged. Only flooded land (dams, irrigation dams and reservoirs) and peatlands are included in the managed wetland definition. Natural systems like rivers and lakes classified under unmanaged wetlands.

**Settlements:** Artificial surfaces are reported under Settlements. These include;

- Urban fabric (continuous, discontinuous fabric)
- Industrial, commercial and transport units (Industrial or commercial units, Road and rail networks and associated land, Port areas, Airports)
- Mine, dump and construction sites (Mineral extraction sites, Dump sites, Construction sites, )
- Artificial, non-agricultural vegetated areas (Green spaces like parks and cemeteries that are not classified as forest, sport and leisure facilities)

**Other Land:** Open spaces with little or no vegetation are defined under Other Land. These include;

- Beaches, dunes, sands
- Bare rocks,
- Sparsely vegetated areas

**Information on approaches used for representing land areas and on land-use databases used for the inventory preparation**

In the previous submission there was inconsistency between activity data of forestry and other land uses. The AD related to forest land was collected from a tabular database called ENVANIS. The ENVANIS system is the major data source of forest management in Turkey and provides both area data, increment and other relevant data related to the forests. It bases on 10 years rotation period field measurements that are implemented on 10 percent of the forests in the country. The ENVANIS system provides high

accuracy information on stand parameters but has some disadvantages for GHG inventories. These disadvantages are;

- The forest area in ENVANIS system uses national legal forest definition and is not compatible with land cover maps i.e. CORINE. Thus it is not possible to establish a consistent land use matrix with a combination of ENVANIS and spatial databases that base on land cover.
- As 10 percent of the country forests are sampled and measured every year the data given in ENVANIS represents only this amount of updated data.
- The types of conversions are unknown. The forest area increase or decrease is reported but the land use that forest is converted is not. Thus an assumption was made that these area areas are all grassland.

The new system still uses data from ENVANIS such as annual increment but not the area data. Below are the specifications of the satellite based system that has been produced just to be used for GHG calculations.

**The New Satellite Based Land Cover Monitoring System (SBLMS)**

A satellite Earth Observation based on AD monitoring system for LULUCF for the entire territory of Turkey is developed. The system relies on wall-to-wall spatially explicit mappings to analyze LULUCF activity data and changes for the period from 1990 to 2015. The system delivers complete annual land use and land use change matrices, allowing for consistent spatially explicit assessment in high spatial resolution (30m, 1 ha MMU). The matrices report on land use and land use change between the six IPCC Guidelines land use categories and related 11 subcategories. With this system every unit of land is univocally assigned to only one land use category, eliminating double counting or omissions. By providing consistent information on all land use and land use change categories, inconsistencies in previous submissions in land use representation derived from CORINE Land Cover and ENVANIS have been overcome.

**Figure 6.3 The temporal structure of the SBLMS with the satellites used**

Following similar approaches of other Mediterranean countries, this is achieved through

- a detailed mapping of the selected reference years (here 1990, 2000 and 2015) from time series high-resolution satellite images,
- the determination of changes between these reference years and,
- an assessment of the intermediate years through advanced analyses.

**Table 6.3 Classification approach for all categories and subcategories under SBLMS**

| ***Category*** | ***Classification Approach*** |
|---|---|
| ***Forest*** | *The identification of **deciduous** and **coniferous** forests is based on time-series analysis, where phonological changes are used to differentiate between these two classes. Copernicus HRL Forest layers 2015 and 2012 are used as ground truth. Following this differentiation a local filter with a size of 1ha will be applied, where areas without dominant tree type are classified as **mixed** forest.* |
| ***Cropland*** | *Separation of cropland and grassland is a complex task in image classification and requires multitemporal data analyses and reference ground truth data. **Annual** crops have been identified due to their vegetation phenology (periodic change of vegetation status). **Perennial** crops on the other hand are hard to differentiate from forest areas, due to similar spectral characteristics compared to other woody vegetation. Therefore, ancillary information is needed to assist in the identification of perennial croplands (e.g.. LPIS for 2015). The global NASA Crop layer and CORINE are used to prepare samples for both crop sub-categories. A fully automated classification approach for 25 years over entire Turkey cannot reliably detect different crop types, so statistical information (e.g. TUIK) can instead be used to calculate crop type ratios that are then applied to the detected crop areas, assuming the area estimates in the TUIK database are representative for the entire country.* |
| ***Grassland*** | *Grassland areas are classified by the spectral characteristics detected over time. The differentiation between woody grasslands and herbaceous grasslands base on spectral classification as well a ruleset to improve accuracy. Woody grasslands, for example, are likely to be found around forests, so their proximity to a forest boundary has been taken into consideration. For the consistency woody grasslands that have a crown closure of 1 to 10 percent are merged with Other Forested Areas category.* |
| ***Wetland*** | *Open (artificial) waterbodies are readily detectable with satellite data given their sudden appearance at a fixed point in time (e.g. construction of a dam) and their permanence following that date. Different indices (e.g. Normalized Difference Water Index (NDWI)) are used to efficiently delineate wetlands. Auxiliary data on dam constructions is needed to improve detection accuracy.* |
| ***Settlement*** | *For the identification of settlement areas, indices like the NDVI are used, as they highlight both vegetated and non-vegetated areas. The HRL and CORINE datasets have been used to provide ground truth.* |
| ***Other land*** | *Areas which are covered by bare soil, sand, rocks, and salt marshes will be classified as other land. Permanent snow and ice will also fall under this category, should they be present in Turkey in any given year.* |

**Land use baseline establishment**

For each of the three reference years (1990, 2000 and 2015) a land cover map has been produced by applying the classification procedures described above. The outputs have further been refined using existing datasets for Turkey especially for the differentiation of perennial crops. Due to the different type and amount of data available for the different time steps, specific methodologies have been applied to achieve consistent outputs over the entire 1990-2015 periods.

2015 is the most recent reference year for mapping and AD reporting in this project. With the Copernicus program, the availability of high resolution satellite imagery has dramatically improved and the monitoring system can utilize this wealth of information by including both Sentinel 2 (10-20m) and Landsat 8 (30m) imagery in the production process. In addition to the high availability of satellite imagery, an extensive list of highly accurate, spatially explicit information products have been used to support the mapping in 2015. These include LPIS, Copernicus High Resolution Layers (HRL) for Forest, Wetlands, Grassland, and Settlements, other global data layers (e.g. USGS Global Crop Maps) and other auxiliary data.

Mapping of the intermediate reference year 2000 is primarily based on Landsat 7 with support from Landsat 5 imagery. CORINE is used as auxiliary data.

The reference year 1990 is the base year for UNFCCC reporting and relies primarily on Landsat 5 imagery for mapping. Considering the 20-year-transition rule, it was anticipated that the time from 1970 until 1990 be reviewed for the definition of the 1990 map (see D4.2.1). The Landsat satellite program started in 1972, however, satellite data is only sparsely available for Turkey until the 1980´s and the assessment of approaches chosen by other Mediterranean countries show that the primary input for 1990 base maps are national forest statistics. The Turkish national forest inventory is available for 1972, however, it is not spatially explicit and uses an incompatible definition for forest which means that it is of very limited use in an assessment of the 1970-1990 period. In order to overcome these high uncertainties, some countries (e.g. Greece) have chosen to report 1990 as is and commence with any land use changes from then on. In our approach we used the 1990 land cover / land use map on Landsat 5 imagery as the base year.
The monitoring system uses an accurate approach by performing change detection for intermediate years through breakpoint analyses of spectral indices calculated from all satellite data available for the intermediate period. This method provides accurate estimates of changes
and their change years, and together with the 3 national land cover / land use maps, provides the basis for the annual matrices.

**Figure 6.4 Change detection approach between reference years**

The satellite based land monitoring system is planned to be continued and improved in the coming years.

**Land Use Matrices**

Land uses and transitions between the 6 land use types and 11 land use subcategories have been calculated in annual land use / land use change matrices for all 25 years (without any interpolation in between). Further the last 3 years (2016, 2017 and 2018) have been extrapolated. All transitions are reported as transitions for 20 years following the transition event. Land categories and subcategories have been further disaggregated into 8 ecozones and 28 forest regional directorates. The ecozones have been explained above in 6.2. The outline of the core matrix is illustrated in Table 6.4

**Table 6.4 A sample land use matrix (2015)**

| TO: / FROM: | Forest land (managed) | Forest land (unmanaged) | Cropland | Grassland (managed) | Grassland (unmanaged) | Wetlands (managed) | Wetlands (unmanaged) | Settlements | Other land | Total unmanaged land | Initial area |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (kha) | | | | | | | | | | |
| Forest land (managed)[2] | 22723.46 | NO | 4.37 | 4.41 | NO | 0.39 | NO | 0.44 | 2.16 | NO | 22735.23 |
| Forest land (unmanaged)[2] | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Cropland[2] | 2.31 | NO | 26871.50 | 0.10 | NO | 1.86 | NO | 1.63 | 1.32 | NO | 26878.71 |
| Grassland (managed)[2] | 61.81 | NO | 5.32 | 23974.34 | NO | 1.06 | NO | 0.70 | 1.51 | NO | 24044.74 |
| Grassland (unmanaged)[2] | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Wetlands (managed)[2] | NO | NO | 0.19 | 0.09 | NO | 465.68 | NO | 0.03 | 0.24 | NO | 466.23 |
| Wetlands (unmanaged)[2] | NO | NO | NO | NO | NO | NO | 1344.22 | NO | NO | NO | 1344.22 |
| Settlements[2] | NO | NO | NO | NO | NO | 0.00 | NO | 1383.70 | 0.01 | NO | 1383.71 |
| Other land[2] | 0.14 | NO | 0.46 | 0.18 | NO | 0.26 | NO | 0.06 | 1672.49 | NO | 1673.60 |
| Total unmanaged land[3] | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| **Final area** | 22787.72 | NO | 26881.83 | 23979.13 | NO | 469.25 | 1344.22 | 1386.55 | 1677.73 | NO | 78526.44 |
| **Net change[4]** | 52.50 | NO | 3.12 | -65.61 | NO | 3.02 | 0.00 | 2.84 | 4.13 | NO | 0.00 |

## Accuracy Assessment

For the land cover and land use datasets of the years 1990, 2000 and 2015 a scientifically sound thematic accuracy assessment has been carried out following best-practice standards according to ISO 19157 Geographic information - Data quality, the CEOS guidelines for Calibration and Validation and the QA4EO principles. This involves the following core design principles:

- Sampling design: A probability sampling design is used to generate a stratified random point sample that is statistically viable for all sampled categories and sub-categories at a confidence interval of 95%.
- Response design: The samples are then validated against higher quality data that includes aerial imagery (e.g. Google and Bing maps) for 2015; 15m pan-sharpened Landsat 7 imagery for 2000 and Landsat 5 imagery for 1990, in addition to other independent aerial or very high resolution satellite imagery, other map products or local auxiliary data.
- Analysis: The outcomes are presenting uncertainty measures on the area and area changes of the land use categories in the form of a land use matrix (Table 6.4) that provides information on overall thematic accuracy, class-specific user's and producer's accuracies, and Kappa coefficients at a confidence interval of 95%. User accuracy and Producer accuracy are defined as follows:

User accuracy is a measure of commission error: Represents the probability that a pixel classified into a given category actually represents that category on the ground. Producer accuracy is a measure of omission error. This value represents how well reference pixels of the ground cover type are classified.

### Completeness

As regards the inventory completeness, sinks and sources that has been reported with notation keys NA, NO and NE in the CRF tables are listed below:

**Table 6.5 Completeness Table**

| Sink/source category | Pool | GHG | Reported as | Mandatory | Explanation |
|---|---|---|---|---|---|
| Forest land remaining forest land | Soil | $CO_2$ | NO | No | It is assumed that carbon stocks of soils in Forest Land Remaining Forest Land do not change. |
| Forest land remaining forest land | Dead wood and litter | $CO_2$ | NO | No | It is assumed that carbon stocks of DOM in Forest Land Remaining Forest Land do not change. |
| Land converted to Forest land | Dead wood | $CO_2$ | NO | Yes | The DW carbon stocks in case of land conversion is assumed to be not changing and DW carbon stocks in all land uses is assumed to be zero. The IPCC 2006 does not provide a default value for DW C stocks. |
| Forest land, Biomass Burning-Controlled Burning | Biomass | $CO_2$, $CH_4$ and $N_2O$ | NO | Yes | Controlled Burning is not applied in Forest land. |
| Forest lands, drained soils | Biomass | Non-$CO_2$ | NE | Yes | No available data on drainage |
| Drained wetlands | Biomass | Non-$CO_2$ | NO | Yes | Wetland drainage is not performed in Turkey. |
| Croplands, grasslands, wetlands and settlements, biomass burning | Biomass | $CO_2$, $CH_4$ and $N_2O$ | NA | Yes | No available data |

## 6.2. Forest Land (4.A)

### Source Category Description:

The forest land category includes CSC from Forest Land Remaining Forest Land (FL-FL) and Land Converted to Forest Land (L-FL) subcategories. Tier 2 methods that are combinations of national EFs and IPCC methods have been applied except some default coefficients (i.e. CF, root to shoot ratio). The AD in these subcategories have entirely been changed. The previous submissions used to base on ENVANIS statistics for AD and increment values. With the spatially explicit land tracking system the increment values are still taken from ENVANIS but AD has entirely been changed. The improvements in this category with the new reporting system and consequences are as follows;

- The forest definition has been changed to one that is more suitable for GHG inventories. The previous national definition was a legal definition that do not include threshold for crown closure. All land uses have been disaggregated into ecozones but forests have also been split into 28 regional forestry directorates. This will enable to implement mitigation actions more effective among forestry directorates.

- Now the forest land has been split into 4 subcategories that are coniferous, deciduous, mixed forest and other forested land (OFL). OFL are forest areas with crown closure between 1 to 10 percent. The previous forest definition included a minimum area of 3 ha. The new system defines all forests with a minimum area of 1 ha.

- As a consequence of changes in definition and AD development methodology the total forest did not change significantly but productive forest areas that have crown closure more than 10 percent increased significantly. As a result of this the removals due to increase in aboveground biomass increased drastically. The increment data taken from ENVANIS puts forward large increases in increment which may be caused by rehabilitation projects in early 2000s. The productivity of the stands increased as the stands reached to the fast growing young ages in 2010s. The changes in increment for forest types are given below;

**Table 6.6 Increment rates of forest types in Turkey (m³/ha)**

| Year | Coniferous | Deciduous | Mixed | OFL |
|---|---|---|---|---|
| 1990 | 2.99 | 2.40 | 2.62 | 0.22 |
| 1995 | 3.06 | 2.46 | 2.68 | 0.23 |
| 2000 | 3.26 | 2.62 | 2.86 | 0.24 |
| 2005 | 3.85 | 2.81 | 3.05 | 0.26 |
| 2010 | 3.98 | 2.94 | 3.06 | 0.22 |
| 2015 | 4.37 | 4.31 | 3.53 | 0.23 |
| 2016 | 4.01 | 4.52 | 3.52 | 0.23 |
| 2017 | 4.24 | 4.43 | 3.61 | 0.23 |
| 2018 | 4.24 | 4.43 | 3.61 | 0.23 |

- The previous system was based on ENVANIS that was available since 2002. The period before 2002 was extrapolated basis of 1972 and 1999's forest inventory. With the new system a consistent land use and land use change AD has been available for the whole reporting period. The AD base on satellite images and has 1 ha spatial resolution. Since 2018 ENVANIS has not been produced by GDF, 2017 values was used for 2018.
- The previous system was not able to identify land conversions between forests and other land uses (i.e. L-FL, FL-CL, FL-GL) and it was assumed that conversions occur only from and to grasslands. Now all land conversions have been tracked with high accuracy and emissions/removals have been reported.
- The previous system was based on reports from regional forestry districts and was not subject to verification while the new system enables verification of the satellite based maps from other sources (i.e. Land Parcel Identification System, CORINE).
- The crown closure data from ENVANIS was based on subjective observations while the new system enabled objective automatic identification.
- The AD of the previous system was derived from management unit of GDF while AD has been produced by an international remote sensing company. This strengthens the objectiveness of the AD.

**Information on Land Classification and Activity Data**

Detailed information has been provided under section 6.3.

**Land-use definitions and the classification systems**

In the previous submissions national forest definition was used. With this submission the forest definition has been changed to a definition in line with the definitions of the Food and Agriculture Organization of the United Nations. The EU and FAO compliant forest definition of 10% crown cover, 1 ha MMU and 5m tree height is applied to all sub-categories. The lands below 10 percent crown closure are classified under other forested land (OFL) as a subcategory under forest land. Agriculturally used tree crops are classified under perennial croplands and are not part of the forest definition.
The forests have further been classified as coniferous, deciduous and mixed forests. The mixed forests consist of both coniferous and deciduous trees with neither species clearly dominating the stand.

**Table 6.7 Forest area (kha) changes in Turkey, 1990-2018**

| Year | Tabular (old system) | | | Spatially explicit land tracking (new system) | | |
|---|---|---|---|---|---|---|
| | Productive forest | Other Forested Land | Total | Productive forest | Other Forested Land | Total |
| 1990 | 10 494 | 10 075 | 20 569 | 19 721 | 3 258 | 22 979 |
| 1995 | 10 546 | 10 125 | 20 672 | 19 699 | 3 248 | 22 955 |
| 2000 | 10 643 | 10 218 | 20 861 | 19 664 | 3 242 | 22 908 |
| 2005 | 10 662 | 10 586 | 21 248 | 19 637 | 3 218 | 22 865 |
| 2010 | 11 203 | 10 334 | 21 537 | 19 583 | 3 184 | 22 783 |
| 2015 | 12 704 | 9 639 | 22 343 | 19 548 | 3 171 | 22 726 |
| 2017 | 13 359 | 9 716 | 23 075 | 19 583 | 3 183 | 22 766 |

The increment data is provided by the Management Department of the Forest Service (GDF) via ENVANIS system. The ENVANIS database (Table 6.8) collects and processes data from forest management plans as the plans are renewed every ten years. Since 2002, the ENVANIS database, a forest resources inventory based on forest management units is used. This database covers the data of areas, annual increment, commercial volume and growing stock of each forest management unit by the species, management types, form of stand, purpose, etc. Therefore, comparison of forest area, annual increment and growing stock, between two subsequent years, has been possible since 2002.

The comparison of removals by forestry sector, according to the forest area, growing stock changes and annual increment since 1990 is given in Table 6.7, 6.10 and 6.11.

**Table 6.8 The ENVANIS Database**

Microsoft Excel (Ürün Etkinleştirilemedi) - Envanis 2014.xlsm

| PLAN CODE NO | | | Features of management type | | | | | | Area | | | | TOTAL FOREST AREA Ha | | Growing stock | | | | Annual Increment | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | High Forests | | Coppices | | | | High | | Coppices | | High | | Coppices | |
| REGION | Forest enterprises | PLANING UNIT | Purpose (Functiion, Statu) | Form of Forest | Management Type | tree species | mixed | | Productive Ha. | Degraded Ha. | Productive Ha. | Degraded Ha. | | (a) Age Class high forests Ha | Productive m3 | Degraded m3 | Productive Stere | Degraded Stere | Productive m3 | Degraded m3 | Productive Stere | Degraded Stere |
| | B | C | | | G | H | I | J | Q | R | S | T | U | AB | AG | AH | AI | AJ | AK | AL | AM | AN |
| 1 | 101 | 10101 | A | 1 | A | K | 63 | F | 0 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 101 | 10101 | M | 11 | A | K | 30 | D | 11,2 | 0 | 0 | 0 | 11,2 | 0 | 2367 | 0 | 0 | 0 | 39 | 0 | 0 | 0 |
| 1 | 101 | 10101 | M | 6 | A | K | 1 | C | 33 | 0 | 0 | 0 | 33,0 | 0 | 3620 | 0 | 0 | 0 | 247 | 0 | 0 | 0 |
| 1 | 101 | 10101 | M | 10 | A | K | 8 | B | 830 | 3310,2 | 0 | 0 | 4140,2 | 632,8 | 2539 | 8330 | 0 | 0 | 187 | 780 | 0 | 0 |
| 1 | 101 | 10101 | T | 6 | A | K | 8 | C | 2044 | 137,1 | 0 | 0 | 2181,1 | 1255,4 | 40950 | 274 | 0 | 0 | 2498 | 14 | 0 | 0 |
| 1 | 101 | 10101 | M | 3 | A | K | 1 | A | 643,4 | 194,4 | 0 | 0 | 837,8 | 174,6 | 4965 | 1166 | 0 | 0 | 433 | 224 | 0 | 0 |
| 1 | 101 | 10102 | O | 1 | A | K | 1 | B | 5039,5 | 238,2 | 0 | 0 | 5277,7 | 1592,2 | 97768 | 925 | 0 | 0 | 8087 | 69 | 0 | 0 |
| 1 | 101 | 10102 | A | 1 | A | K | 51 | F | 0 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 101 | 10102 | T | 5 | A | K | 8 | A | 1281,4 | 52,6 | 0 | 0 | 1334,0 | 636,8 | 16208 | 210 | 0 | 0 | 867 | 13 | 0 | 0 |
| 1 | 101 | 10102 | F | 9 | A | K | 53 | F | 0 | 6741,4 | 0 | 0 | 6741,4 | 0 | 0 | 18447 | 0 | 0 | 0 | 923 | 0 | 0 |
| 1 | 101 | 10102 | M | 5 | A | K | 11 | A | 26,9 | 50,4 | 0 | 0 | 77,3 | 0 | 1484 | 132 | 0 | 0 | 45 | 8 | 0 | 0 |
| 1 | 101 | 10102 | M | 10 | A | K | 1 | A | 19,3 | 0 | 0 | 0 | 19,3 | 0 | 963 | 0 | 0 | 0 | 54 | 0 | 0 | 0 |
| 1 | 101 | 10102 | M | 11 | A | K | 1 | A | 8,1 | 0 | 0 | 0 | 8,1 | 0 | 310 | 0 | 0 | 0 | 26 | 0 | 0 | 0 |
| 1 | 101 | 10103 | O | 1 | A | K | 1 | B | 1217,4 | 211,3 | 0 | 0 | 1428,7 | 322,4 | 39524 | 2113 | 0 | 0 | 2596 | 63 | 0 | 0 |
| 1 | 101 | 10103 | O | 1 | A | K | 1 | A | 6299,8 | 963,8 | 0 | 0 | 7263,6 | 505,2 | 423652 | 9588 | 0 | 0 | 18407 | 288 | 0 | 0 |
| 1 | 101 | 10103 | A | 1 | A | K | 51 | F | 0 | 0 | 0 | 0 | 0,0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 101 | 10103 | T | 5 | A | K | 8 | A | 278,9 | 6,5 | 0 | 0 | 285,4 | 124 | 4920 | 26 | 0 | 0 | 271 | 1 | 0 | 0 |
| 1 | 101 | 10103 | M | 10 | A | K | 1 | A | 1691,3 | 1474,1 | 0 | 0 | 3165,4 | 138,3 | 59647 | 12935 | 0 | 0 | 3224 | 397 | 0 | 0 |
| 1 | 101 | 10103 | M | 3 | A | K | 1 | A | 1528,4 | 760,8 | 0 | 0 | 2289,2 | 6,4 | 67073 | 7455 | 0 | 0 | 3896 | 224 | 0 | 0 |
| 1 | 101 | 10103 | M | 3 | A | K | 1 | A | 1611,5 | 484,6 | 0 | 0 | 2096,1 | 69,9 | 144351 | 4090 | 0 | 0 | 6225 | 120 | 0 | 0 |
| 1 | 101 | 10103 | F | 6 | A | K | 1 | A | 105,7 | 31,6 | 0 | 0 | 137,3 | 0 | 6875 | 282 | 0 | 0 | 316 | 8 | 0 | 0 |
| 1 | 101 | 10103 | M | 3 | A | K | 1 | A | 18,1 | 10 | 0 | 0 | 28,1 | 0 | 1426 | 20 | 0 | 0 | 56 | 1 | 0 | 0 |

Sayfa6 / Sayfa3 / Sayfa2 / MENU / **ENVANIS** / SEFLDOK / AMACL / FORM+KARSM / AGACTURL / LLDOK / degerlAGT / degerl / TUM

### Databases to Identify Forests

There are only two documents (1972 and 1999 inventory) relevant to the national forest inventory results in Turkey before 2002. The first document showing 1972 situation was presented in 1980, and the second was prepared at the end of 1999. Because of the absence of regular national forest inventory works in Turkey, both of the results were obtained based on the summaries of management plans data renewed in every ten years interval. The data provided by the first inventory (1972) has been shown in Table 6.9. The growing stock and annual increment data since 1990 have been presented in Tables 6.10 and 6.11.

**Table 6.9 Forest inventory, 1972 (Source: GDF)**

| **Areas** | | | | | | |
|---|---|---|---|---|---|---|
| | **Productive[a]** | | **Degraded[b]** | | **Total** | |
| **Type** | **ha** | **%** | **ha** | **%** | **ha** | **%** |
| **High Forest** | 6 176 899 | 30.58 | 4 757 708 | 23.55 | 10 934 607 | 54.13 |
| **Coppice** | 2 679 558 | 13.27 | 6 585 131 | 32.60 | 9 264 689 | 45.87 |
| **Total** | 8 856 457 | 43.85 | 11 342 839 | 56.15 | 20 199 296 | 100.00 |
| **Growing stock** | | | | | | |
| | **Productive[a]** | | **Degraded[b]** | | **Total** | |
| **Type** | **$m^3$** | **%** | **$m^3$** | **%** | **$m^3$** | **%** |
| **High Forest** | 758 732 197 | 81.10 | 54 349 847 | 5.81 | 813 082 044 | 86.91 |
| **Coppice[c]** | 88 300 818 | 9.44 | 34 129 288 | 3.65 | 122 430 106 | 13.09 |
| **Total** | 847 033 015 | 90.54 | 88 479 135 | 9.46 | 935 512 150 | 100.00 |
| **Annual volume increment** | | | | | | |
| | **Productive[a]** | | **Degraded[b]** | | **Total** | |
| **Type** | **$m^3$** | **%** | **$m^3$** | **%** | **$m^3$** | **%** |
| **High Forest** | 20 791 672 | 74.09 | 1 343 744 | 4.79 | 22 135 416 | 78.88 |
| **Coppice[c]** | 4 813 197 | 17.15 | 1 114 592 | 3.97 | 5 927 789 | 21.12 |
| **Total** | 25 604 869 | 91.24 | 2 458 336 | 8.76 | 28 063 205 | 100.00 |

a) Crown closure between 0.11–1.00.

b) Crown closure between 0.01–0.10.

c) 0.75 coefficient was used to convert the stere volume to a $m^3$ volume.

**Table 6.10 Growing stock, 1990-2018 (Source: GDF)**

**(thousand m³)**

| | Productive[1] | | | Degraded[2] | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **High Forest** | **Coppices[3]** | **Productive total** | **High Forest** | **Coppices[3]** | **Degraded total** | **Total** |
| 1990 | 984 907 | 64 986 | 1 049 893 | 43 622 | 12 038 | 19 976 | 1 105 553 |
| 1995 | 1 028 346 | 67 957 | 1 096 303 | 45 618 | 12 589 | 20 890 | 1 154 509 |
| 2000 | 1 087 582 | 72 002 | 1 159 584 | 48 334 | 13 338 | 22 134 | 1 221 256 |
| 2005 | 1 177 849 | 71 551 | 1 249 400 | 51 045 | 12 661 | 23 655 | 1 313 106 |
| 2010 | 1 328 437 | 59 097 | 1 387 534 | 49 351 | 12 286 | 19 415 | 1 449 171 |
| 2015 | 1 552 821 | 33 695 | 1 586 516 | 59 997 | 11 954 | 71 951 | 1 658 467 |
| 2016 | 1 540 723 | 29 215 | 1 569 939 | 60 895 | 10 377 | 71 271 | 1 641 210 |
| 2017 | 1 601 931 | 13 728 | 1 615 659 | 64 991 | 4 314 | 69 306 | 1 684 964 |
| 2018 | 1 601 931 | 13 728 | 1 615 659 | 64 991 | 4 314 | 69 306 | 1 684 964 |

1) Crown closure between 0.11–1.00.

2) Crown closure between 0.01–0.10.

3) 0.75 coefficient was used to convert the stere volume to a $m^3$ volume.

**Table 6.11 Annual volume increment, 1990-2018 (Source: GDF)**

**(m³)**

| | Productive[1] | | | Degraded[2] | | | |
|---|---|---|---|---|---|---|---|
| **Years** | **High Forest** | **Coppices[3]** | **Productive total** | **High Forest** | **Coppices[3]** | **Degraded total** | **Total** |
| 1990 | 28 263 488 | 3 594 725 | 31 858 213 | 1 292 180 | 761 076 | 2 053 256 | 33 911 468 |
| 1995 | 28 997 951 | 3 697 360 | 32 695 311 | 1 329 099 | 782 820 | 2 111 919 | 34 807 230 |
| 2000 | 31 047 474 | 3 985 847 | 35 033 320 | 1 432 875 | 843 943 | 2 276 819 | 37 310 139 |
| 2005 | 33 282 485 | 4 025 038 | 37 307 523 | 1 495 502 | 922 183 | 2 417 685 | 39 725 208 |
| 2010 | 37 857 085 | 3 089 208 | 40 946 293 | 1 468 070 | 792 878 | 2 260 948 | 43 207 241 |
| 2015 | 46 011 103 | 1 511 832 | 47 522 935 | 1 484 455 | 585 191 | 2 069 646 | 49 592 580 |
| 2016 | 43 669 510 | 1 277 030 | 44 946 540 | 1 539 688 | 487 331 | 2 027 019 | 46 973 559 |
| 2017 | 45 516 439 | 755 697 | 46 272 136 | 1 728 694 | 252 728 | 1 981 422 | 48 253 588 |
| 2018 | 45 516 439 | 755 697 | 46 272 136 | 1 728 694 | 252 728 | 1 981 422 | 48 253 588 |

1) Crown closure between 0.11–1.00 (productive forest).

2) Crown closure between 0.01–0.10 (degraded).

3) 0.75 coefficient was used to convert the stere volume to a m3 volume.

Evaluation of Table 6.9, 6.10, and 6.11 can be outlined as below:

1. The growing stocks and annual volume increments of the coppice forests reduced while high forests increased constantly. The highest amount of decrease in growing stock/annual increment has occurred in degraded coppices due to converting the coppices into high forests.
2. The total amount of growing stocks and annual volume increment in the coniferous and deciduous forests have slightly decreased.

The considerable reasons for these changes can be:

1. The changing approaches on the forestry applications towards multi-functional use of forest resources in the framework of sustainable forest management concept,
2. Converting coppices into the high forests,
3. The reforestation of unstocked areas in and around forests and rehabilitation of degraded forests by the GDF.

All the factors focused above has been played affecting roles on these changes. Almost entire of Turkish forests can be categorized in the temperate climate zone.

**CSC in Forest Land Remaining Forest Land**

The carbon stock change in FL-FL subcategory has been net removals during the reporting period. The driver of this situation was the increment of forests. The increment of the forests in the country increased for the reporting period constantly while increased faster for some years. The steep increase in 2015 was due to difference in increment ($m^3$/ha) for 2014 ($Iv_{dec}$=4.08, $Iv_{con}$=2.99, $Iv_{mixed}$=2.99, $Iv_{deg}$=0.18) and 2015 ($Iv_{dec}$=4.37, $Iv_{con}$=4.31, $Iv_{mixed}$=3.53, $Iv_{deg}$=0.23). This might have caused by extensive rehabilitation campaigns during 2000s.

The increment data is derived from all management units of the country as explained in methodology section.

**Figure 6.5 Gains and losses in Forest land Remaining Forest land subcategory (FL-FL)**

**CSC in Land Converted to Forest Land**

The CSC in Land Converted to Forest land category is not a key category anymore with the new reporting system. The main reason for the drop in L-FL removals is due to change in forest definition. As explained in the section 6.2 the forest definition has been changed to a physical definition while it used to be a legal national definition. As a consequence of this the AD for land converted to forest land decreased substantially. The CSC in L-FL subcategory moved from net loss to net gain during the reporting period though large fluctuations are observed (Figure 6.6). The large loss in CSC in 1992 was due to a relatively larger conversion from grassland to forest. As explained in methodology section below the conversion from grassland to forest land causes loss in living biomass carbon for the first year.

**Figure 6.6 Gains and losses in Land Converted to Forest land subcategory (L-FL)**

As seen from graph above (Figure 6.6) the L-FL gains increased until 2011 and stabilized since then. There have been 3 type of transitions occurred during the reporting period;

- Grassland Converted to Forest land
- Other land Converted to Forest land
- Cropland (Perennial) Converted to Forest land

Between 1991 and 1996 the conversions were around 4000 ha per year, then dropped below 2000 between 1997 to 2000 and then rise again until 2010. The conversions to Forest land drop to a band around 2000 since then.

**Figure 6.7 Area data for Land Converted to Forest land subcategory**

As seen from the Figure 6.7 the major conversion path in L-FL subcategory is the conversions from Grassland to Forest land. The driver of this conversion type is the afforestation/reforestation of grasslands in or around the forests.

**Table 6.12 Area of Land converted to forest land (kha)**

| *Years* | *GL-FL* | *CL-FL* | *OL-FL* | *Years* | *GL-FL* | *CL-FL* | *OL-FL* |
|---|---|---|---|---|---|---|---|
| **1990** | 0.00 | 0.00 | 0.00 | **2005** | 3.47 | 0.15 | 0.40 |
| **1991** | 3.40 | 0.07 | 0.56 | **2006** | 7.35 | 0.22 | 0.77 |
| **1992** | 6.71 | 0.14 | 1.00 | **2007** | 4.28 | 0.17 | 0.57 |
| **1993** | 2.97 | 0.08 | 0.45 | **2008** | 5.51 | 0.18 | 1.01 |
| **1994** | 3.28 | 0.08 | 0.32 | **2009** | 3.63 | 0.10 | 0.34 |
| **1995** | 3.32 | 0.10 | 0.41 | **2010** | 5.84 | 0.18 | 0.56 |
| **1996** | 2.89 | 0.09 | 0.30 | **2011** | 2.15 | 0.08 | 0.25 |
| **1997** | 1.02 | 0.04 | 0.11 | **2012** | 2.56 | 0.13 | 0.29 |
| **1998** | 1.24 | 0.06 | 0.23 | **2013** | 0.86 | 0.05 | 0.08 |
| **1999** | 0.63 | 0.07 | 0.28 | **2014** | 1.34 | 0.06 | 0.15 |
| **2000** | 0.30 | 0.03 | 0.10 | **2015** | 1.45 | 0.09 | 0.14 |
| **2001** | 2.77 | 0.07 | 0.24 | **2016** | 1.68 | 0.08 | 0.18 |
| **2002** | 5.67 | 0.21 | 0.68 | **2017** | 1.58 | 0.08 | 0.17 |
| **2003** | 2.77 | 0.11 | 0.35 | **2018** | 1.38 | 0.07 | 0.15 |
| **2004** | 6.07 | 0.24 | 0.74 | | | | |

### Methodological Issues:

**Forest Land Remaining Forest land**

The calculations in FL category is based on 8 ecozones and 28 forestry regional directorates. In this submission soil C stocks for each ecozones have been calculated by TAGEM (General Directorate of Agricultural Research) based on the soil database.

**Above- and below-ground biomass**

Gain-Loss Method (Tier 2) is used to estimate annual change in carbon stocks in living above- and below-ground biomass, considering the country-specific data on mean annual increment, volume of commercial cutting, fuelwood removal and loss due to disturbances, national biomass expansion factors ($BCEF_I$, $BCEF_R$) and basic wood densities (D), and default root-to-shoot ratios (R) and carbon fractions (CF).

Below equations have been used in estimations;

2006 IPCC equations: Vol 4., Ch. 2: 2.7 / 2.9 / 2.10 / 2.11 / 2.12 / 2.13 / 2.14
Estimation approach was as follows;

i. Area of each forest stratum with corresponding mean annual increment have been multiplied by national $BCF_I$ coefficients, IPCC 2006 default root-to-shoot ratios, and IPCC 2006 default CF coefficients to get annual biomass gain ($\Delta C_G$).

The increment data is provided by the Forest Management Department via ENVANIS system and they are updated every year for four forest types;

- Deciduous forest
- Coniferous forest
- Mixed forest
- Degraded forest

The increment data used are given in Table 6.6 for some years.

ii. Annual carbon loss ($\Delta C_L$) as a sum of wood removals (i.e. commercial cutting), fuelwood removal and disturbance (i.e. forest fires) by each forest stratum has been calculated. In calculation of annual carbon losses in biomass due to disturbances ($D_{isturbance}$) the annual area affected by disturbances has been used (see Equation 2.14).

The data used in this step is received from relevant departments (Production and Marketing, Fire etc.) of the GDF.
The annual biomass loss is a sum of losses from commercial round wood felling's, fuelwood gathering and other losses in forest land was calculated by using the following Equation 2.11 of AFOLU Guidance. Biomass gains and biomass losses are estimated separately. For example, commercial round wood felling's have been calculated in a different column as well as fuelwood gathering and other losses according to the Equation 2.12, Equation 2.13 and Equation 2.14 respectively. The calculations of biomass losses are consistent with the IPCC 2006 Guidance for AFOLU (Vol 4).

2006 IPCC equations: Vol 4., Ch. 2: 2.11 / 2.12 / 2.13 / 2.14 / 2.17 /2.24 / 2.27

The FG data in eq. 13 is obtained from the GDF (Forestry Statistic 2018). According to GDF's data, percentage of the illegal cutting is 67, also the fuelwood gathering is 33.
In eq. 2.14 to calculate the losses from wildfires the BW covers the dead organic matter. It is assumed that all dead organic matter is burned in wildfires in this category. It is also assumed that average biomass during wildfires is burned with 44 percent of burning productivity (GDF 2008-2016).

iii. All biomass gains and losses has been summed up from strata to get estimates for FF.

iv. Annual change in carbon stock in biomass has been estimated as a difference between $\Delta C_G$ and $\Delta C_L$.

**Table 6.13 The Average basic wood density and national BCEF's factors (Tolunay, 2013)**

| Vegetation type | Basic wood density (tonnes/m³) | $BCEF_I$ (tonnes/m³) | BCEFs (tonnes/m³) | $BCEF_R$ (tonnes/m³) |
|---|---|---|---|---|
| Coniferous | 0.446 | 0.541 | 0.563 | 0.612 |
| Deciduous | 0.541 | 0.709 | 0.717 | 0.797 |

**Soil and dead organic matter**

Currently, no changes in CSC in deadwood, litter and soil (Tier 1 assumption) are reported due to lack of data related to any change in soil and DOM carbon stocks in FL-FL.

**Land Converted to Forest land**

The annual increments and coefficients used for Land Converted to Forest Land were;

**Table 6.14 Coefficients used to calculate CS and CSC in L-FL**

| Forest Type | Annual Increment m³/ha | $BCEF_I$ | Root to Shoot Ratio tonnes d.m. below-ground biomass/tonnes above-ground d.m. biomass | CF tonnes C/tonnes dm |
|---|---|---|---|---|
| Forest Deciduous | 0.69[1] | 0.709[2] | 0.46[3] | 0.48[3] |
| Forest Coniferous | 0.69 | 0.541[2] | 0.4 | 0.51 |
| Forest Mixed | 0.69 | 0.625 | 0.48 | 0.49 |
| Forest Degraded | 0.69 | 0.625 | 0.44 | 0.49 |

[1]Forest Management Department

[2]Tolunay (2013)

[3]IPCC 2006

The DW C stock has been assumed to be 1 percent of the standing stock. The conversion period is accepted as 20 years.

The DOM C stock is assumed to accumulate in 20 years conversion time to reach a steady state given in Table 6.15 below (Tolunay and Çömez, 2008) :

**Table 6.15 Carbon stocks in DOM used for all forest areas in Turkey**

| **DOM (tonnes/ha)** | | |
|---|---|---|
| Coniferous | 7.51 | ± 6.61 (n=601) |
| Deciduous | 3.09 | ± 1.58 (n=368) |

The below soil C stock values have been applied in case of land use conversions. The stock values have been calculated by the Research Units of Ministry of Agriculture and Forestry.

**Table 6.16 SOC stocks of forests disaggregated for ecozones**

| **Ecozone** | **C stock Forest land (tC/ha)** | **SOC ref** |
|---|---|---|
| Mediterranean Mountain zone | 51.53 | 46.96 |
| Mediterranean coastal zone deciduous and coniferous forest | 46.08 | 37.77 |
| East Anatolian steppe | 48.41 | 47.99 |
| East Anatolian deciduous forest zone | 45.14 | 41.30 |
| Euxine-Colchic deciduous forest | 51.90 | 49.66 |
| Central Anatolian steppe | 49.92 | 40.41 |
| Aegean Inland deciduous and coniferous forest | 50.88 | 42.53 |
| North Anatolian deciduous, coniferous and mixed forest | 55.05 | 54.57 |

Reference to the 2006 IPCC equations: Vol 4., Ch. 2: 2.16 / 2.19

### Uncertainties and Time-Series Consistency:

According to para 15 of 24/CP19 Annex I Parties shall quantitatively estimate the uncertainty of the data used for all source and sink categories using at least Approach 1, and report uncertainties for at least the base year (1990) and last reported year (2018), as well as the trend uncertainty between these two years.

There are two approaches presented in the 2006 IPCC guidelines, which use simple error propagation equations and Monte Carlo or similar techniques, respectively. The first approach has been used with the equations IPCC (2006) equations: Vol. 1, Ch. 3: 3.1 / 3.2.

Uncertainty of input data is provided by underlying systems. Uncertainty of activity data is derived for 11x11 land categories for latest reported year 2015. Under current stage of finalization of land use mapping, still preliminary values of the uncertainty of activity data are estimated in the range of 5% for land remaining in the same category and 10% for land being in conversion among various land categories.

Uncertainty (in %, consistent with 2006 IPCC Guidelines) for CSCs is provided according to various underlying national sources and references.

Uncertainty propagation tracks GHG inventory calculation, i.e. from the most detailed input activity data and CSC/EF to GHG estimates at the land use subcategory and LULUCF sector. Uncertainty is propagated following Tier 1 with Eq. 3.2 of 2006 IPCC Guidelines where uncertain data is added or subtracted, and Eq. 3.1 of 2006 IPCC Guidelines where uncertain data is multiplied or divided.

Estimation of GHG inventory uncertainty cover completely the national territory for year 1990 as the base year and last reported year (2018). Wherever CSC in a C pool is reported as NO or NA such estimates are not included in the Tier 1 propagation of uncertainty.

For all C pools subject to 20 years transition the uncertainty estimation considers aggregation of two terms:

a) uncertainty associated to the CSC for the area in the first year of the conversion which involves the uncertainty of C stocks in land use from before and after conversion, and the uncertainty of CSC in the first year after the conversion, and,

b) uncertainty for rest of the area reported under respective conversion cumulated from previous years.

Table 6.17 shows the relative uncertainty for CSC overall for land subcategories.

**Table 6.17 Uncertainty calculation results for the whole LULUCF sector**

| Summary | BY (1990) | LRY (2018) |
|---|---|---|
| 4A1 | 51% | 50% |
| 4A2 | 0% | 57% |
| 4B1 | 7% | 10% |
| 4B2 | 0% | 47% |
| 4C1 | 0% | 0% |
| 4C2 | 0% | 149% |
| 4D1 | 0% | 0% |
| 4D2 | 0% | 86% |
| 4E1 | 0% | 0% |
| 4E2 | 0% | 26% |
| 4F1 | 0% | 0% |
| 4F2 | 0% | 18% |
| Table 4(I) | 0% | 0% |
| Table 4(II) | 0% | 0% |
| Table 4(III) | 0% | 75% |
| Table 4(IV) | 0% | 387% |
| Table 4(V) | 54% | 54% |
| **LULUCF sector** | **50.80%** | **51.14%** |

The summary table for the uncertainty in Forest land categories (FL-FL and L-FL) is as follows;

**Table 6.18 Uncertainty summary table for Forest land subcategories**

| | BY (1990) | LRY (2018) |
|---|---|---|
| Forest land Remaining Forest land | | |
| 4A1 – FL-FL | 51% | 50% |
| ΔCC in Living Biomass | 51% | 50% |
| Annual Loss Living Biomass (ΔCL) | 33% | 34% |
| Annual Gain Living Biomass (ΔCG) | 35% | 35% |
| Net C stock change in Litter (ΔCC) | NA | NA |
| Net C stock change in Dead Wood (ΔCC) | NA | NA |
| Net C stock change in SOM (ΔCC) | NA | NA |
| Land Converted to Forest land | | |
| 4A2 – L-FL | 0% | 57.1% |
| ΔCC in Living Biomass | NA | 4.9% |
| Annual Loss Living Biomass (ΔCL) | NA | 22.6% |
| Annual Gain Living Biomass (ΔCG) | NA | 4.9% |
| Net C stock change in Dead Wood (ΔCC) | NA | NA |
| Net C stock change in Litter (ΔCC) | NA | 300.7% |
| Net C stock change in SOM (ΔCC) | NA | 47.0% |

Two forest inventories were carried out by the GDF for 1972 and 1999. ENVANIS has been started since 2002. The data on growing stocks and annual increments during 1990-2002 period were calculated by interpolation among data of these three inventories (1972, 1999 and 2002). Thus, the annual increases of growing stocks and volume increments were assumed as linear. The annual ENVANIS table has been obtained annually from the Management and Planning Department of GDF since 2002.

The time series consistency of area data has been significantly increased by using the same satellite images and methods as explained above.

The statistics on the forest fires and commercial round wood production for the same period and fuelwood gathering data were taken from GDF.

### Source-Specific QA/QC and Verification:

The QA/QC procedure has been realized in the framework of plan developed and carried out by TurkStat the national inventory agency. The sector specific QA/QC has been realized during the LULUCF project activities mentioned above. The calculation procedures have been checked and discussed with the LULUCF experts in and out of the agencies.

### Recalculation:

As explained above the area based AD in the Forest land sector moved from ENVANIS to spatially explicit land tracking system. This enabled the production of a consistent land use matrix that determines the land use and conversions with 1 ha accuracy. The forest land category emissions/removals for the previous and new system are given below;

**Figure 6.8 The comparison of C emissions/removals between the previous and current system estimations**

The removals increased significantly as productive forest area has been detected with the new spatially explicit land tracking system as larger compared to previous system. Since the increment data and other coefficients did not change the removals increased.

On the other hand, removals from L-FL decreased significantly with the new system. The reason for this was the change in AD.

### Planned Improvement:

The Forest land is the major category. The removals base on the increment data while emissions on the harvest. An improvement plan has been developed for the sector in the framework of the LULUCF project. The plan has three basic scales; short (ST), medium (MT) and long terms (LT).

The planned improvements for Forest land category are;

- Re-evaluation of the emission/other factors used for living biomass, DOM, and mineral soils (ST, MT) based on Mediterranean Emission/Other factors Database by the collaboration program of ONF-GDF.
- Estimation of carbon stocks for carbon pools for which emissions are currently not reported, namely deadwood, litter and mineral soil (MT)
- Preparation of input forest data and parameters for some of existing forest models (e.g. CBM) to be able for running simulations and making projections of forest development under different scenarios (MT, LT)
- Development and establishment of national forest inventory (NFI) based on permanent sample plot system (LT)
- Use a higher Tier level in reporting (MT, LT).
- Develop and use allometric equations instead of currently used national BCEF coefficients (MT, LT).

## 6.3. Croplands (4.B)

### Source Category Description:

Estimation of emissions and removals from cropland follows the 2006 IPCC guidelines (Volume 4, Ch. 5). Currently, there are two strata for different crops in Turkey, namely annual and perennial crops. Besides, emissions are estimated due to cultivation of organic soil and direct $N_2O$ emission from N mineralization associated with loss of soil organic matter due to land use change or management of mineral soils.

**Figure 6.9 The changes in net emissions and removals in CL-CL and L-CL subcategories**

The cropland category is net emissions due to conversions to cropland. The CL-CL subcategory becomes removals in some years and emissions in others. The main reason for this is the rate of conversions between annual and perennial crops. The perennial crops assumed to have larger C stocks compared to annual crops as explained in methodology section below. Cropland remaining Cropland and Land converted to Cropland has been reported under this category.

CSC in aboveground, belowground, organic and mineral soil pools have been calculated and reported. The Cropland category was a large source in the last submission but has diminished with the change in emission factors and activity data.

The Cropland covers all perennial and annual crops in agriculture lands. Orchards and poplars are included in this category.

**Information on Land Classification and Activity Data**

The CL-CL area decreases during the reporting period due to conversions to other land uses but stabilize after around 2010 and increases after 2015 as lands in L-CL are added after 2010 (20 years transition period).

**Figure 6.10 The change in area of CL-CL**

**Figure 6.11 The change in area of L-CL**

On the other hand, the area of L-CL increases but not with the same ration as conversions from croplands. Thus the cropland area in total decreases during the reporting period.

**Land-use definitions and the classification systems**

Activity data for cropland remaining cropland have been subdivided into annual and perennial crops. Cropland category includes all annual and perennial crops including orchards including olives, vineyards and poplar plantations; the change in all carbon pools has been assumed to be not changing for annual and perennial crops. The increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year. However, CSC have been calculated in case of conversions between annual and perennial croplands.

### Methodological Issues:

**Annual cropland remaining annual cropland**

*Above- and below-ground biomass*

For annual crops increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in that same year (IPCC 2006).

*Dead organic matter*

According to Tier 1 method there is no need to estimate the carbon stock changes for DOM.

*Mineral and organic soils*

Currently, there is no specific data on management systems in the country to apply reference carbon stocks and stock change factors. Emissions from organic soil are estimated using default equation and emission factors.

Reference to 2006 IPCC equations: Vol. 4., Ch. 2: 2.24 / 2.25 / 2.26

**Perennial cropland remaining perennial cropland**

*Above- and below-ground biomass*

At present, the Gain-Loss method has been applied to estimate CSC in biomass pool. The accumulation rate and rotation period for perennial crops was assumed according to values used by inventory of Italy. If perennial crops, such as vineyards, orchards and olive groves can be disaggregated regarding spatially-explicit activity data, then default values for carbon stocks at maturity, rotation periods,

biomass accumulation rates etc. for these crops can be obtained from the MediNet Biomass Report (Canaveira et al., 2018).

Reference to 2006 IPCC equation: Vol. 4., Ch. 2: 2.7

Since the size of loss due to harvesting is usually not available for perennial woody biomass, the CSC in living biomass has been assumed to be compensated with the harvest of the trees. Hence C gains due to the increment of the perennial trees are neutralized by the loss due to cutting of the trees at 100/rotation period of the total perennial crops area. The rotation period of perennial croplands is assumed to be 20 years, with 15 tons C/ha when mature. Thus the increment is 0.75 tons C/ha/yr.

*Dead organic matter*

According to Tier 1 method the carbon stock changes for DOM has not been estimated. If specific national data on different crop and climate types and management practices or periodic inventories are improved then Gain-Loss or Stock-Difference method, respectively, can be applied.

*Mineral and organic soils*

Currently, there is no specific data on management systems in the country to apply reference carbon stocks and stock change factors. Tier 1 method can be applied when these data become available. Emissions from organic soil has been estimated using a default equation and emission factor.

Reference to 2006 IPCC equations: Vol. 4., Ch. 2: 2.24 / 2.25 / 2.26

**Annual cropland converted to perennial cropland**

The 2006 IPCC guidelines do not include any specific method for conversions between annual and perennial cropland. As carbon accumulation rates and soil carbon stocks in these two cropland subcategories are different, more accurate estimation of emissions and removals is needed.

Annual CSC in biomass has be estimated using the equation below:

*Annual change in biomass = conversion area for a transition period of 20 years * $\Delta C_{growth}$ + annual area of currently converted land * $\Delta C_{conversion}$*

$\Delta C_{conversion} = C_{after} - C_{before}$

$C_{after}$ = carbon stock immediately after conversion (at Tier 1 assume $C_{after} = 0$)

$C_{before}$ = carbon stock of annual crop before conversion (IPCC default value = 5 t C $ha^{-1}$)

$\Delta C_{growth}$ = carbon accumulation rate of perennial crops (0.75 t C $ha^{-1}$ $yr^{-1}$)

The biomass loss is accounted only for the year of conversion, thus $\Delta C_{conversion}$ must be multiplied by annual area (i.e. area in the year of conversion).
Reference to 2006 IPCC equations: Vol. 4., Ch. 2: 2.15 / 2.16

The calculation spreadsheet for annual-perennial conversion is as follows;

**Table 6.19 Coefficients and CS values used in annual/perennial conversions in cropland category**

| Ecozones | NAI Y1 ΔC*G* (tC/yr/ha) | Loss Y1 ΔCL (tC/yr/ha) | BAFTER (tC/yr) | BBEFORE (tC/yr | CSC Y1 (tC/ha/yr) | NAI Y2 (tC/ha/yr) |
|---|---|---|---|---|---|---|
| Mediterranean Mountain zone | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |
| Mediterranean coastal zone deciduous and coniferous forest | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |
| East Anatolian steppe | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |
| East Anatolian deciduous forest zone | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |
| Euxine-Colchic deciduous forest | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |
| Central Anatolian steppe | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |
| Aegean Inland deciduous and coniferous forest | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |
| North Anatolian deciduous, coniferous and mixed forest | 0.75 | 0 | 0 | 5 | -4.25 | 0.75 |

As seen from the Table 6.19 CS for annual crops is 5 tC/ha and is lost in the first year of conversion while the planted seedlings grow with 0.75 tC/ha per year for the next 20 years until the land is allocated as CL-CL.

*Dead organic matter*

According to Tier 1 method carbon stock changes for DOM assumed to be not changing.

*Mineral and organic soil*

According to Tier 2 method country-specific carbon stocks have been used to estimate annual change in organic carbon stocks in mineral soil. Country-specific carbon stocks have been calculated by the TAGEM (General Directorate of Agricultural Research) and used for both cropland subcategories in case of conversion, default equation, assuming a transition period of 20 years has been used. Emissions from organic soil should be estimated using a default equation and emission factors.

Reference to 2006 IPCC equations: Vol. 4., Ch. 2: 2.24 / 2.25 / 2.26

The below default coefficients have been employed to calculate CSC in mineral soils in case of conversions (between cropland subcategories or LULUCF land use categories) CS for annual and perennial croplands. The SOC of perennial crops has been assumed to be same as $SOC_{ref}$.

**Table 6.20 Coefficients and soil CS values used in annual/perennial conversions in cropland category**

| Ecozone | SOC ref (tC/ha) | $CS_{annualcrops}$ (tC/ha) | $CS_{perennialcrops}$ (tC/ha) |
|---|---|---|---|
| Mediterranean Mountain zone | 46.96 | 40.22 | 46.96 |
| Mediterranean coastal zone deciduous and coniferous forest | 37.77 | 29.62 | 37.77 |
| East Anatolian steppe | 47.99 | 38.90 | 47.99 |
| East Anatolian deciduous forest zone | 41.30 | 30.44 | 41.30 |
| Euxine-Colchic deciduous forest | 49.66 | 38.68 | 49.66 |
| Central Anatolian steppe | 40.41 | 32.14 | 40.41 |
| Aegean Inland deciduous and coniferous forest | 42.53 | 30.99 | 42.53 |
| North Anatolian deciduous, coniferous and mixed forest | 54.57 | 34.29 | 54.57 |

**Perennial cropland converted to annual cropland**

Annual CSC in biomass on areas of conversion from perennial cropland to annual cropland has been estimated by the same equation as for the opposite management change with the difference that only annual area of currently converted land is considered here, because the gains of the annual crop during land use changes to annual cropland are accounted only once.

The estimation of CSC in biomass has been performed using the equation below:

*Annual change in biomass = annual area of currently converted land *($\Delta C_{conversion}$ + $\Delta C_{growth}$)*

$\Delta C_{conversion} = C_{after} - C_{before}$

$C_{after}$ = carbon stock immediately after conversion (at Tier 1 assume $C_{after} = 0$)

$C_{before}$ = carbon stock of annual/perennial crop before conversion (15 t C $ha^{-1}$)

$\Delta C_{growth}$ = carbon accumulation rate of annual/perennial crop (IPCC default value = 5 t C $ha^{-1}$)

*Dead organic matter*

According to Tier 1 method carbon stock changes for DOM assumed to be not changing.

*Mineral and organic soil*

According to Tier 2 method country-specific carbon stocks have been used to estimate annual change in organic carbon stocks in mineral soil. Country-specific carbon stocks have been calculated by the TAGEM (General Directorate of Agricultural Research) and used for both cropland subcategories in case of conversion, default equation, assuming a transition period of 20 years has been used. Emissions from organic soil should be estimated using a default equation and emission factors.

Reference to 2006 IPCC equations: Vol. 4., Ch. 2: 2.24 / 2.25 / 2.26

**Land converted to cropland**

*Above- and below-ground biomass*

Changes in biomass carbon stocks have been estimated according to Tier 1/Tier 2 method with spatially-explicit activity data. Conversions from all other land uses (e.g. from forest land, grassland etc.) to cropland are likely to occur in the country. The principle of estimating the CSC in biomass in land converted to cropland is same as described in the subcategories annual cropland converted to perennial and vice versa, depending on conversion to which cropland subcategory happened (i.e. annual or perennial cropland).

Below calculation algorithms have been applied for land conversions to Cropland;
In case of forest land converted to annual and perennial cropland;

**Table 6.21 Coefficients and CS values used in L-CL category**

| Ecozone | | CF | ΔCG (tC/yr/ha) | ΔCL (tC/yr/ha) | $B_{AFTER}$ (tC/yr/ha) | $B_{BEFORE}$ (tC/ha) | CSC Y1 (tC/ha/yr) | CSC Y2 (tC/ha/yr) |
|---|---|---|---|---|---|---|---|---|
| **For FL-CLannual** | | | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 0.48 | 5.00 | 0 | 0 | 41.97 | -36.97 | 0 |
| | Forest Coniferous | 0.51 | 5.00 | 0 | 0 | 64.80 | -59.80 | 0 |
| | Forest Mixed | 0.49 | 5.00 | 0 | 0 | 52.35 | -47.35 | 0 |
| | Forest Degraded | 0.49 | 5.00 | 0 | 0 | 4.051 | 0.95 | 0 |
| **For FL-CLperennial** | | | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 0.48 | 0.75 | 0 | 0 | 41.97 | -41.22 | 0.75 |
| | Forest Coninferous | 0.51 | 0.75 | 0 | 0 | 64.80 | -64.05 | 0.75 |
| | Forest Mixed | 0.49 | 0.75 | 0 | 0 | 52.35 | -51.60 | 0.75 |
| | Forest Degraded | 0.49 | 0.75 | 0 | 0 | 4.05 | -3.30 | 0.75 |

In case of grassland converted to annual and perennial cropland;

| **For GL-CLannual** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ecozone | | ΔCG (tC/yr/ha) | ΔCL (tC/yr/ha) | $B_{AFTER}$ (tC/yr/ha) | $B_{BEFORE}$ (tC/ha) | CSC Y1 (tC/ha/yr) | CSC Y2 (tC/ha/yr) |
| i.e. Mediterranean Mountain zone | GL-CLann | 5.00 | 0 | 0 | 1.86 | 3.14 | 0 |
| **For GL-CLannual** | | | | | | | |
| i.e. Mediterranean Mountain zone | GL-CLper | 0.75 | 0 | 0 | 1.86 | -1.11 | 0.75 |

In case of wetland (managed/unmanaged) converted to annual and perennial cropland;

| **For WLmanaged/unmanaged-CLannual** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ecozone | | ΔCG (tC/yr/ha) | ΔCL (tC/yr/ha) | $B_{AFTER}$ (tC/yr/ha) | $B_{BEFORE}$ (tC/ha) | CSC Y1 (tC/ha/yr) | CSC Y2 (tC/ha/yr) |
| i.e. Mediterranean Mountain zone | WLman-CLann | 5.00 | 0 | 0 | 1.86 | 3.14 | 0 |
| i.e. Mediterranean Mountain zone | WLunman-CLann | 5.00 | 0 | 0 | 1.86 | 3.14 | 0 |
| **For WLmanaged/unmanaged-CLperennial** | | | | | | | |
| i.e. Mediterranean Mountain zone | WLman-CLper | 0.75 | 0 | 0 | 1.86 | -1.11 | 0.75 |
| i.e. Mediterranean Mountain zone | WLunman-CLper | 0.75 | 0 | 0 | 1.86 | -1.11 | 0.75 |

In case of settlement converted to annual and perennial cropland;

| For SL-CLannual | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ecozone | | ΔCG (tC/yr/ha) | ΔCL (tC/yr/ha) | $B_{AFTER}$ (tC/yr/ha) | $B_{BEFORE}$ (tC/ha) | CSC Y1 (tC/ha/yr) | CSC Y2 (tC/ha/yr) |
| i.e. Mediterranean Mountain zone | SL-CLann | 5.00 | 0 | 0 | 5.03 | -0.03 | 0 |
| **For SL-CLperennial** | | | | | | | |
| i.e. Mediterranean Mountain zone | SL-CLper | 0.75 | 0 | 0 | 5.03 | -4.28 | 0.75 |

In case of other land converted to annual and perennial cropland;

| For OL-CLannual | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ecozone | | ΔCG (tC/yr/ha) | ΔCL (tC/yr/ha) | $B_{AFTER}$ (tC/yr/ha) | $B_{BEFORE}$ (tC/ha) | CSC Y1 (tC/ha/yr) | CSC Y2 (tC/ha/yr) |
| i.e. Mediterranean Mountain zone | OL-CLann | 5 | 0 | 5 | 0 | 0 | 0 |
| **For OL-CLperennial** | | | | | | | |
| i.e. Mediterranean Mountain zone | OL-CLper | 0.75 | 0 | 0 | 0 | 0.75 | 0.75 |

*Dead organic matter*

A Tier 1 method takes into account the estimation of CSC in dead organic matter only for major conversion categories (e.g. forest land to cropland). It is assumed that all dead organic matter is removed in the year of conversion, so there is no accumulation in land converted to cropland afterwards.

Reference to 2006 IPCC equation: Vol. 4., Ch. 2: 2.23,

**Table 6.22 Coefficients and CS values used in L-CL category**

| **For FL-CLannual/perennial** | | | | | | |
|---|---|---|---|---|---|---|
| Ecozone | | CFlitter | CFdw | CSC LT (tC/ha) | CSC DW (tC/ha) | CSC DOM (tC/ha) |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 0.37 | 0.50 | -3.09 | -0.49 | -3.58 |
| | Forest Coninferous | 0.37 | 0.50 | -7.51 | -0.36 | -7.87 |
| | Forest Mixed | 0.37 | 0.50 | -5.30 | -0.42 | -5.72 |
| | Forest Degraded | 0.37 | 0.50 | 0.00 | -0.03 | -0.03 |

*Mineral and organic soil*

The Tier 2 method has been applied here, as country-specific reference carbon stocks were available for all land categories. General approach, assuming the 20-year transition period after which the soil reaches a new equilibrium, has been used for land use changes to cropland. In case that organic soil is subject to this type of land-use change, emissions have be estimated using the default emission factor and method.

Reference to 2006 IPCC equations: Vol. 4., Ch. 2: 2.24 / 2.25 / 2.26

In case of forest land (FL) converted to annual and perennial cropland;

**Table 6.23 Coefficients and soil CS values used in L-CL category**

| Ecozone | Forest Type | C stock Forest land (tC/ha) | SOC ref | C stock Cropland (tC/ha) | CSC Y1 (tC/ha/yr) | NAI Y2 (tC/ha/yr) |
|---|---|---|---|---|---|---|
| **FL-CLannual** | | | | | | |
| Mediterranean Mountain zone | FL-CLann | 51.53 | 46.96 | 40.22 | -0.57 | -0.57 |
| Mediterranean coastal zone deciduous and coniferous forest | FL-CLann | 46.08 | 37.77 | 29.62 | -0.82 | -0.82 |
| East Anatolian steppe | FL-CLann | 48.41 | 47.99 | 38.90 | -0.48 | -0.48 |
| East Anatolian deciduous forest zone | FL-CLann | 45.14 | 41.30 | 30.44 | -0.74 | -0.74 |
| Euxine-Colchic deciduous forest | FL-CLann | 51.90 | 49.66 | 38.68 | -0.66 | -0.66 |
| Central Anatolian steppe | FL-CLann | 49.92 | 40.41 | 32.14 | -0.89 | -0.89 |
| Aegean Inland deciduous and coniferous forest | FL-CLann | 50.88 | 42.53 | 30.99 | -0.99 | -0.99 |
| North Anatolian deciduous, coniferous and mixed forest | FL-CLann | 55.05 | 54.57 | 34.29 | -1.04 | -1.04 |
| **FL-CLperennial** | | | | | | |
| Mediterranean Mountain zone | FL-CLper | 51.53 | 46.96 | 46.96 | -0.23 | -0.23 |
| Mediterranean coastal zone deciduous and coniferous forest | FL-CLper | 46.08 | 37.77 | 37.77 | -0.42 | -0.42 |
| East Anatolian steppe | FL-CLper | 48.41 | 47.99 | 47.99 | -0.02 | -0.02 |
| East Anatolian deciduous forest zone | FL-CLper | 45.14 | 41.30 | 41.30 | -0.19 | -0.19 |
| Euxine-Colchic deciduous forest | FL-CLper | 51.90 | 49.66 | 49.66 | -0.11 | -0.11 |
| Central Anatolian steppe | FL-CLper | 49.92 | 40.41 | 40.41 | -0.48 | -0.48 |
| Aegean Inland deciduous and coniferous forest | FL-CLper | 50.88 | 42.53 | 42.53 | -0.42 | -0.42 |
| North Anatolian deciduous, coniferous and mixed forest | FL-CLper | 55.05 | 54.57 | 54.57 | -0.02 | -0.02 |

In case of grassland (GL) converted to annual and perennial cropland;

| Ecozone | SOC ref | C stock Grassland (tC/ha) | C stock Cropland (annual) (tC/ha) | CSC Y1 (tC/ha/yr) | NAI Y2 (tC/ha/yr) |
|---|---|---|---|---|---|
| **GL-CLannual** | | | | | |
| Mediterranean Mountain zone | **46.96** | **42.26** | **40.22** | -0.10 | -0.10 |
| Mediterranean coastal zone deciduous and coniferous forest | **37.77** | **33.99** | **29.62** | -0.22 | -0.22 |
| East Anatolian steppe | **47.99** | **43.19** | **38.90** | -0.21 | -0.21 |
| East Anatolian deciduous forest zone | **41.30** | **37.17** | **30.44** | -0.34 | -0.34 |
| Euxine-Colchic deciduous forest | **49.66** | **44.69** | **38.68** | -0.30 | -0.30 |
| Central Anatolian steppe | **40.41** | **36.37** | **32.14** | -0.21 | -0.21 |
| Aegean Inland deciduous and coniferous forest | **42.53** | **38.28** | **30.99** | -0.36 | -0.36 |
| North Anatolian deciduous, coniferous and mixed forest | **54.57** | **49.11** | **34.29** | -0.74 | -0.74 |
| **GL-CLperennial** | | | | | |
| Mediterranean Mountain zone | **46.96** | **42.26** | **46.96** | 0.23 | 0.23 |
| Mediterranean coastal zone deciduous and coniferous forest | **37.77** | **33.99** | **37.77** | 0.19 | 0.19 |
| East Anatolian steppe | **47.99** | **43.19** | **47.99** | 0.24 | 0.24 |
| East Anatolian deciduous forest zone | **41.30** | **37.17** | **41.30** | 0.21 | 0.21 |
| Euxine-Colchic deciduous forest | **49.66** | **44.69** | **49.66** | 0.25 | 0.25 |
| Central Anatolian steppe | **40.41** | **36.37** | **40.41** | 0.20 | 0.20 |
| Aegean Inland deciduous and coniferous forest | **42.53** | **38.28** | **42.53** | 0.21 | 0.21 |
| North Anatolian deciduous, coniferous and mixed forest | **54.57** | **49.11** | **54.57** | 0.27 | 0.27 |

In case of wetland (WL) (Managed/Unmanaged) converted to annual and perennial cropland;

| Parameteres /C stock in year (tC/yr/ha) | **SOC ref** | **C stock Wetlands (tC/ha)** | **C stock Cropland (annual) (tC/ha)** | CSC Y1 (tC/ha/yr) | NAI Y2 (tC/ha/yr) |
|---|---|---|---|---|---|
| **WL-CLannual** | | | | | |
| Mediterranean Mountain zone | **46.96** | **42.26** | **40.22** | -0.10 | -0.10 |
| Mediterranean coastal zone deciduous and coniferous forest | **37.77** | **33.99** | **29.62** | -0.22 | -0.22 |
| East Anatolian steppe | **47.99** | **43.19** | **38.90** | -0.21 | -0.21 |
| East Anatolian deciduous forest zone | **41.30** | **37.17** | **30.44** | -0.34 | -0.34 |
| Euxine-Colchic deciduous forest | **49.66** | **44.69** | **38.68** | -0.30 | -0.30 |
| Central Anatolian steppe | **40.41** | **36.37** | **32.14** | -0.21 | -0.21 |
| Aegean Inland deciduous and coniferous forest | **42.53** | **38.28** | **30.99** | -0.36 | -0.36 |
| North Anatolian deciduous, coniferous and mixed forest | **54.57** | **49.11** | **34.29** | -0.74 | -0.74 |
| **WL-CLperennial** | | | | | |
| Mediterranean Mountain zone | **46.96** | **42.26** | **46.96** | 0.23 | 0.23 |
| Mediterranean coastal zone deciduous and coniferous forest | **37.77** | **33.99** | **37.77** | 0.19 | 0.19 |
| East Anatolian steppe | **47.99** | **43.19** | **47.99** | 0.24 | 0.24 |
| East Anatolian deciduous forest zone | **41.30** | **37.17** | **41.30** | 0.21 | 0.21 |
| Euxine-Colchic deciduous forest | **49.66** | **44.69** | **49.66** | 0.25 | 0.25 |
| Central Anatolian steppe | **40.41** | **36.37** | **40.41** | 0.20 | 0.20 |
| Aegean Inland deciduous and coniferous forest | **42.53** | **38.28** | **42.53** | 0.21 | 0.21 |
| North Anatolian deciduous, coniferous and mixed forest | **54.57** | **49.11** | **54.57** | 0.27 | 0.27 |

In case of settlements (SL) converted to annual and perennial cropland;

| Ecozones | C stock Settlements (tC/ha) | SOC ref | C stock Cropland (annual) (tC/ha) | CSC Y1 (tC/ha/yr) | NAI Y2 (tC/ha/yr) |
|---|---|---|---|---|---|
| **SL-CLannual** | | | | | |
| Mediterranean Mountain zone | **20.14** | **46.96** | **40.22** | 1.00 | 1.00 |
| Mediterranean coastal zone deciduous and coniferous forest | **20.14** | **37.77** | **29.62** | 0.47 | 0.47 |
| East Anatolian steppe | **20.14** | **47.99** | **38.90** | 0.94 | 0.94 |
| East Anatolian deciduous forest zone | **20.14** | **41.30** | **30.44** | 0.51 | 0.51 |
| Euxine-Colchic deciduous forest | **20.14** | **49.66** | **38.68** | 0.93 | 0.93 |
| Central Anatolian steppe | **20.14** | **40.41** | **32.14** | 0.60 | 0.60 |
| Aegean Inland deciduous and coniferous forest | **20.14** | **42.53** | **30.99** | 0.54 | 0.54 |
| North Anatolian deciduous, coniferous and mixed forest | **20.14** | **54.57** | **34.29** | 0.71 | 0.71 |
| **SL-CLperennial** | | | | | |
| Mediterranean Mountain zone | **20.14** | **46.96** | **46.96** | 1.34 | 1.34 |
| Mediterranean coastal zone deciduous and coniferous forest | **20.14** | **37.77** | **37.77** | 0.88 | 0.88 |
| East Anatolian steppe | **20.14** | **47.99** | **47.99** | 1.39 | 1.39 |
| East Anatolian deciduous forest zone | **20.14** | **41.30** | **41.30** | 1.06 | 1.06 |
| Euxine-Colchic deciduous forest | **20.14** | **49.66** | **49.66** | 1.48 | 1.48 |
| Central Anatolian steppe | **20.14** | **40.41** | **40.41** | 1.01 | 1.01 |
| Aegean Inland deciduous and coniferous forest | **20.14** | **42.53** | **42.53** | 1.12 | 1.12 |
| North Anatolian deciduous, coniferous and mixed forest | **20.14** | **54.57** | **54.57** | 1.72 | 1.72 |

In case of otherland (OL) converted to annual and perennial cropland;

| Ecozones | C stock Otherland (tC/ha) | SOC ref | C stock Cropland (annual) (tC/ha) | CSC Y1 (tC/ha/yr) | NAI Y2 (tC/ha/yr) |
|---|---|---|---|---|---|
| **OL-CLannual** | | | | | |
| Mediterranean Mountain zone | **12.78** | **46.96** | **40.22** | 1.37 | 1.37 |
| Mediterranean coastal zone deciduous and coniferous forest | **12.78** | **37.77** | **29.62** | 0.84 | 0.84 |
| East Anatolian steppe | **12.78** | **47.99** | **38.90** | 1.31 | 1.31 |
| East Anatolian deciduous forest zone | **12.78** | **41.30** | **30.44** | 0.88 | 0.88 |
| Euxine-Colchic deciduous forest | **12.78** | **49.66** | **38.68** | 1.30 | 1.30 |
| Central Anatolian steppe | **12.78** | **40.41** | **32.14** | 0.97 | 0.97 |
| Aegean Inland deciduous and coniferous forest | **12.78** | **42.53** | **30.99** | 0.91 | 0.91 |
| North Anatolian deciduous, coniferous and mixed forest | **12.78** | **54.57** | **34.29** | 1.08 | 1.08 |
| **OL-CLperennial** | | | | | |
| Mediterranean Mountain zone | **12.78** | **46.96** | **46.96** | 1.71 | 1.71 |
| Mediterranean coastal zone deciduous and coniferous forest | **12.78** | **37.77** | **37.77** | 1.25 | 1.25 |
| East Anatolian steppe | **12.78** | **47.99** | **47.99** | 1.76 | 1.76 |
| East Anatolian deciduous forest zone | **12.78** | **41.30** | **41.30** | 1.43 | 1.43 |
| Euxine-Colchic deciduous forest | **12.78** | **49.66** | **49.66** | 1.84 | 1.84 |
| Central Anatolian steppe | **12.78** | **40.41** | **40.41** | 1.38 | 1.38 |
| Aegean Inland deciduous and coniferous forest | **12.78** | **42.53** | **42.53** | 1.49 | 1.49 |
| North Anatolian deciduous, coniferous and mixed forest | **12.78** | **54.57** | **54.57** | 2.09 | 2.09 |

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.24 Uncertainty summary table for Cropland subcategories**

| | BY (1990) | LRY (2018) |
|---|---|---|
| Cropland Remaining Cropland | | |
| 4B1 – CL-CL | 7.3% | 9.9% |
| Net C stock change in Living Biomass (ΔCC) | 0.0% | 12.6% |
| Net C stock change in DOM (ΔCC) | NA | NA |
| Net C stock change in SOM (ΔCC) | 7.3% | 15.3% |
| Land Converted to Cropland | | |
| 4B2 – L-CL | 0% | 47% |
| ΔCC in Living Biomass | NA | 46% |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in Dead Organic Matter (ΔCC) | NA | 42% |
| Net C stock change in SOM (ΔCC) | NA | 64% |

### Source-Specific QA/QC and Verification:

The QA/QA procedure has been realized in the framework of plan developed and carried out by TurkStat the national inventory agency. The sector specific QA/QC has been realized during the LULUCF project activities mentioned above. The calculation procedures have been checked and discussed with the LULUCF experts in and out of the agencies.

### Recalculation:

There is no recalculation for this submission in this category.

### Planned Improvement:

The planned improvements for Cropland category are;

- Increase from Tier 1 to Tier 2 method in estimating the carbon stock change in living biomass in Land converted to cropland (MT)
- Collection, sampling and/or modelling of carbon stocks in mineral soil at larger spatial scale (e.g. consider potential use of National Geospatial Soil Fertility and Soil Organic Carbon Information System) (MT)

- Data collection about management systems (land use, tillage, input) for Cropland remaining cropland, also through use of existing generalised maps of dominant crops in Turkey (MT)

## 6.4. Grassland (4.C)

### Source Category Description:

Grasslands are all lands with non woody vegetation subject to grazing. CSC in grasslands is assumed to be not changing if management is not changed. Actually, there are grassland rehabilitation projects implemented in the country but conservatively we assumed no change in biomass. We plan to report these projects as the grassland monitoring system becomes available. Emissions from organic soils are reported assuming that all grasslands are managed. Default EFs are used in this procedure but the AD is disaggregated for climate types.

**Figure 6.12 The change in net emissions in Grassland category**

**Information on Land Classification and Activity Data**

The grassland areas decrease in Turkey though there are a certain amount of conversions to grasslands. While around a total of 0.08 M ha are added to grasslands during the reporting period the grassland area decreased from 24.23 Mha to 24.03 ha.

**Figure 6.13 The change in area of GL-GL**

**Figure 6.14 The change in area of L-GL**

## Methodological Issues:

### Grassland remaining grassland (GL-GL)

All carbon pools in GL-GL is assumed to be not changing thus reported as NO except emissions from organic soils. A 3.01 k ha of organic soils have been reported in GL-GL subcategory. This caused a 0.03

k t $CO_2$ eq. of emissions every year during the reporting period. The management in these areas are not known exactly but considered as managed to be conservative.

**Land converted to grassland (GL-GL)**

*Above- and below-ground biomass*

**Table 6.25 Coefficients and living biomass CS values for L-GL subcategories**

| Ecozones | Forest type | NAI Y1 ΔCG (tC/yr/ha) | Loss Y1 ΔCL (tC/yr/ha) | BAFTER (tC/yr/ha) | BBEFORE (tC/yr/ha) | CSC Y1 (tC/ha/yr) |
|---|---|---|---|---|---|---|
| **Forest land converted to Grassland** | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 1.86 | 0 | 0 | 41.97 | -40.11 |
| | Forest Coninferous | 1.86 | 0 | 0 | 64.80 | -62.94 |
| | Forest Mixed | 1.86 | 0 | 0 | 52.35 | -50.49 |
| | Forest Degraded | 1.86 | 0 | 0 | 4.05 | -2.19 |
| **Cropland (annual) converted to Grassland** | | | | | | |
| | $Cropland_{annual}$ | 1.86 | 0 | 0 | 5 | -3.14 |
| **Cropland (perennial) converted to Grassland** | | | | | | |
| | $Cropland_{perennial}$ | 1.86 | 0 | 0 | 15 | -13.14 |
| **Wetland converted to Grassland** | | | | | | |
| | Grassland | 1.86 | 0 | 0 | 1.86 | 0.00 |
| **Settlements converted to Grassland** | | | | | | |
| | Settlements | 1.86 | 0 | 0 | 5.03 | -3.17 |
| **Otherland converted to Grassland** | | | | | | |
| | Other land | 1.86 | 0 | 0 | 0 | 1.86 |

*Dead organic matter*

CSC converted to wetlands for forest lands are calculated based on the below coefficients and EF. The CSC for other conversions are assumed to be not occurring.

**Table 6.26 Coefficients and DOM CS values for L-GL subcategories**

| Ecozones | Forest type | CF litter | CF Dead Wood | CSC LT (tC/ha/yr) | CSC DW (tC/ha/yr) | CSC DOM (tC/ha/yr) |
|---|---|---|---|---|---|---|
| **Forest land converted to Grassland** | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 0.37 | 0.50 | -3.09 | -0.49 | -3.58 |
| | Forest Coninferous | 0.37 | 0.50 | -7.51 | -0.36 | -7.87 |
| | Forest Mixed | 0.37 | 0.50 | -5.30 | -0.42 | -5.72 |
| | Forest Degraded | 0.37 | 0.50 | 0.00 | -0.03 | -0.03 |

*Mineral and organic soil*

The CSC in mineral soils have been calculated based on national stock values determined by General Directorate of Agricultural Research. The default conversion duration of 20 years has been applied.

**Table 6.27 Coefficients and soil CS values for L-GL subcategories**

| Ecozone | SOC ref | C stock Grassland (tC/ha) | Forest land C stock (tC/ha) | Cropland (Annual) C stock (tC/ha) | Cropland (perennial) C stock (tC/ha) | Wetland C stock (tC/ha) | Settl. C stock (tC/ha) | Otherl. C stock (tC/ha) |
|---|---|---|---|---|---|---|---|---|
| Mediterranean Mountain zone | 46.96 | 42.26 | 51.53 | 40.22 | 46.96 | 42.26 | 20.14 | 12.78 |
| Mediterranean coastal zone deciduous and coniferous forest | 37.77 | 33.99 | 46.08 | 29.62 | 37.77 | 33.99 | 20.14 | 12.78 |
| East Anatolian steppe | 47.99 | 43.19 | 48.41 | 38.90 | 47.99 | 43.19 | 20.14 | 12.78 |
| East Anatolian deciduous forest zone | 41.30 | 37.17 | 45.14 | 30.44 | 41.30 | 37.17 | 20.14 | 12.78 |
| Euxine-Colchic deciduous forest | 49.66 | 44.69 | 51.90 | 38.68 | 49.66 | 44.69 | 20.14 | 12.78 |
| Central Anatolian steppe | 40.41 | 36.37 | 49.92 | 32.14 | 40.41 | 36.37 | 20.14 | 12.78 |

**Table 6.28 Coefficients and soil CS values for L-GL subcategories (Cont'd)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Aegean Inland deciduous and coniferous forest | 42.53 | 38.28 | 50.88 | 30.99 | 42.53 | 38.28 | 20.14 | 12.78 |
| North Anatolian deciduous, coniferous and mixed forest | 54.57 | 49.11 | 55.05 | 34.29 | 54.57 | 49.11 | 20.14 | 12.78 |

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.29 Uncertainty summary table for Grassland subcategories**

| | BY (1990) | LRY (2018) |
|---|---|---|
| Grassland Remaining Grassland | | |
| 4C1 – GL-GL | 0 | 0 |
| ΔCC in Living Biomass | NO | NA |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | NO | NA |
| Net C stock change in SOM (ΔCC) | 0.00 | NA |
| Land Converted to Grassland | | |
| 4C2 – L-GL | 0% | 149% |
| ΔCC in Living Biomass | NA | 32% |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | NA | 190% |
| Net C stock change in SOM (ΔCC) | NA | 149% |

### Source-Specific QA/QC and Verification:

The Qa/Qc procedure has been realized in the framework of plan developed and carried out by TurkStat the national inventory agency. The sector specific Qa/Qc has been realized during the LULUCF project activities mentioned above. The calculation procedures have been checked and discussed with the LULUCF experts in and out of the agencies.

### Recalculation:

There is no recalculation for this submission in this category.

### Planned Improvement:

The planned improvements for Grassland category are;

- Re-evaluation of the estimation of emissions due to drainage of organic soil (MT)
- Check for the size of emission factors for the subcategory Land converted to grassland (MT)
- Verification of assumptions by surveying national research studies and papers (ST, MT)
- Data collection about management systems (land use, management, input) for Grassland remaining grassland (MT, LT)
- Estimation of carbon stock changes in mineral soil for Grassland remaining grassland, using a default method (applying SOCREF and stock change factors) (MT)
- Modelling of carbon stocks in mineral soil at larger spatial scale (e.g. considering potential use of National Geospatial Soil Fertility and Soil Organic Carbon Information System) (MT, LT

## 6.5. Wetlands (4.D)

### Source Category Description:

Emissions/removals from wetlands remaining wetlands are currently assumed to be not occurring. Two subcategories are currently included under the wetlands remaining wetlands in the CRF table 4.D of Turkey, namely peat extraction remaining peat extraction and flooded land remaining flooded land. The non-official data suggests that peat extraction permission is given for an area that is ignorable in terms of carbon stock changes.

The conversions from and to managed/unmanaged wetlands have been calculated under L-WL subcategory. The emissions and removals calculated were relatively small but had large variations.

**Figure 6.15 The emissions/removals from wetlands category**

As seen from the figure above the emissions in L-WL were around 100 kt $CO_2$ eq. and stable. In 2013 the emissions peaked and then dropped 2015 and even turned to be a slight removal. In 2016 and 2017 the emissions rise again. The driver of the fluctuations in emissions was caused by emissions from living biomass pool due to land conversions.

Estimation of emissions and removals from wetlands follows the 2006 IPCC guidelines (Volume 4, Ch. 7) and 2013 Wetlands Supplement. Wetlands include any land that is covered or saturated by water for all or part of the year, and that does not fall into the Forest Land, Cropland, or Grassland categories (IPCC 2006). In wetlands category emissions are estimated only for managed wetlands due to human activity, such as drainage, rewetting, dam construction etc.

At present, the notation key NO has been used for peat extraction. When more detailed data on peat extraction are available, a default methodology can be applied.

**Information on Land Classification and Activity Data**

The managed wetland area increased constantly during the reporting period causing mostly emissions.

**Figure 6.16 a The change in area of managed wetlands**

**Figure 6.16 b The change in area of unmanaged wetlands**

**Land-use definitions and the classification systems**

All human made reservoirs are included in the managed wetlands category while natural water bodies in the unmanaged wetlands subcategory.

### Methodological Issues:

**Wetland remaining wetland (WL-WL)**

All carbon pools in WL-WL except peat extraction is assumed to be not changing thus reported as NO. The activity data used in peat extraction base on permitted area for extraction by the ministry and depth. We assumed that all permitted area has been subject to production. The on and off site emissions have been estimated in Tier 1 level with default EFs (IPCC Vol. Chapter 7. Table 7.4, 7.5, Temperate zone, nutrient poor).
Reference to 2006 IPCC equations: Vol. 4., Ch. 7: 7.2 / 7.3 /7.4 /7.5

**Land converted to wetland (L-WL)**

*Above- and below-ground biomass*

**Table 6.30 Coefficients and living biomass CS values for L-WL subcategories**

| Ecozones | Forest type | NAI Y1 ΔCG (tC/yr/ha) | Loss Y1 ΔCL (tC/yr/ha) | BAFTER (tC/yr/ha) | BBEFORE (tC/yr/ha) | CSC Y1 (tC/ha/yr) |
|---|---|---|---|---|---|---|
| **Forest land converted to Wetland** | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 1.86 | 0 | 0 | 41.97 | -40.11 |
| | Forest Coninferous | 1.86 | 0 | 0 | 64.80 | -62.94 |
| | Forest Mixed | 1.86 | 0 | 0 | 52.35 | -50.49 |
| | Forest Degraded | 1.86 | 0 | 0 | 4.05 | -2.19 |
| **Cropland (annual) converted to Wetland** | | | | | | |
| | $Cropland_{annual}$ | 1.86 | 0 | 0 | 5 | -3.14 |
| **Cropland (perennial) converted to Wetland** | | | | | | |
| | | 1.86 | 0 | 0 | 15 | -13.14 |
| **Grassland converted to Wetland** | | | | | | |
| | | 0.00 | 0 | 1.86 | 1.86 | 0.00 |
| **Settlements converted to Wetland** | | | | | | |
| | | 1.86 | 0 | 0 | 5.03 | -3.17 |
| **Otherland converted to Wetland** | | | | | | |
| | | 1.86 | 0 | 0 | 0 | 1.86 |

*Dead organic matter*

CSC converted to wetlands for forest lands are calculated based on the below coefficients and EF. The CSC for other conversions are assumed to be not occurring.

**Table 6.31 Coefficients and DOM CS values for L-WL subcategories**

| **Ecozones** | **Forest type** | CF litter | CF Dead Wood | CSC LT (tC/ha/yr) | CSC DW (tC/ha/yr) | CSC DOM (tC/ha/yr) |
|---|---|---|---|---|---|---|
| **Forest land converted to Wetland** | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 0.37 | 0.50 | -3.09 | -0.49 | -3.58 |
| | Forest Coninferous | 0.37 | 0.50 | -7.51 | -0.36 | -7.87 |
| | Forest Mixed | 0.37 | 0.50 | -5.30 | -0.42 | -5.72 |
| | Forest Degraded | 0.37 | 0.50 | 0.00 | -0.03 | -0.03 |

*Mineral and organic soil*

The CSC in mineral soils have been calculated based on national stock values determined by General Directorate of Agricultural Research. The default conversion duration of 20 years has been applied.

**Table 6.32 Coefficients and soil CS values for L-WL subcategories**

| **Ecozone** | **SOC ref** | **C stock Wetlands (tC/ha)** | **Forest land C stock (tC/ha)** | **Cropland (Annual) C stock (tC/ha)** | **Cropland (perennial) C stock (tC/ha)** | **Grassland C stock (tC/ha)** | **Settl. C stock (tC/ha)** | **Otherl. C stock (tC/ha)** |
|---|---|---|---|---|---|---|---|---|
| Mediterranean Mountain zone | 46.96 | 42.26 | 51.53 | 40.22 | 46.96 | 42.26 | 20.14 | 12.78 |
| Mediterranean coastal zone deciduous and coniferous forest | 37.77 | 33.99 | 46.08 | 29.62 | 37.77 | 33.99 | 20.14 | 12.78 |
| East Anatolian steppe | 47.99 | 43.19 | 48.41 | 38.90 | 47.99 | 43.19 | 20.14 | 12.78 |
| East Anatolian deciduous forest zone | 41.30 | 37.17 | 45.14 | 30.44 | 41.30 | 37.17 | 20.14 | 12.78 |
| Euxine-Colchic deciduous forest | 49.66 | 44.69 | 51.90 | 38.68 | 49.66 | 44.69 | 20.14 | 12.78 |

**Table 6.33 Coefficients and soil CS values for L-WL subcategories (Cont'd)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Central Anatolian steppe | 40.41 | 36.37 | 49.92 | 32.14 | 40.41 | 36.37 | 20.14 | 12.78 |
| Aegean Inland deciduous and coniferous forest | 42.53 | 38.28 | 50.88 | 30.99 | 42.53 | 38.28 | 20.14 | 12.78 |
| North Anatolian deciduous, coniferous and mixed forest | 54.57 | 49.11 | 55.05 | 34.29 | 54.57 | 49.11 | 20.14 | 12.78 |

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3. The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.34 Uncertainty summary table for Wetland subcategories**

| | BY (1990) | LRY (2018) |
|---|---|---|
| Wetland Remaining Wetland | | |
| **4D1 – WL-WL** | **0%** | **0** |
| ΔCC in Living Biomass | **NA** | **NA** |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | **NA** | NA |
| Net C stock change in SOM (ΔCC) | **NA** | NA |
| Land Converted to Wetland | | |
| **4D2 – L-WL** | **0%** | **86%** |
| ΔCC in Living Biomass | NA | 33% |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | NA | 195% |
| Net C stock change in SOM (ΔCC) | NA | 183% |

### Source-Specific QA/QC and Verification:

The QA/QC procedure has been realized in the framework of plan developed and carried out by TurkStat the national inventory agency. The sector specific QA/QC has been realized during the LULUCF project activities mentioned above. The calculation procedures have been checked and discussed with the LULUCF experts in and out of the agencies.

### Recalculation:

There is no recalculation for this submission in this category.

### Planned Improvement:

The planned improvements for Wetland category are;

- Use of Wetlands Supplement more effectively (ST, MT)
- Review all existing national and international databases related to wetlands (e.g. Ramsar Convention on Wetlands, FAOSTAT, Wetlands International, NGO data etc.) (MT)
- Expert judgment (e.g. by national soil scientist) about different types of managed wetlands that are likely to occur in Turkey (ST, MT)
- Collection of activity data regarding specific types of managed wetlands (MT)
- Sampling of SOC and estimation of carbon stocks for major soil types of wetlands (MT, LT)

## 6.6. Settlements (4.E)

### Source Category Description:

The carbon stock change in settlements remaining settlements has been estimated to be not changing. Land converted to settlements caused emissions increasing until 2010 and then stabilizing.
The major driver of the emissions has been conversions from other land uses that resulted in loss of carbon.

**Figure 6.17 The change in net emissions in settlements**

**Information on Land Classification and Activity Data**

The area of settlements is increasing constantly with the conversions mainly from cropland and grassland.

**Figure 6.18 The change in area of settlements**

**Land-use definitions and the classification systems**

The emission factors and coefficients for calculation GHG emissions and removals in this category bases on the results of a national research project entitled "*Development of a climate change-ecosystem services software to support sustainable land planning works*" funded by the Scientific and Technical Research Council of Turkey with the Project Number 112Y096.

The method we used to develop EFs for Settlements category bases on a modeling study while representativeness is weak because the study is conducted only in Istanbul. At least 2-3 similar studies are needed to have a higher representativeness. The methodological level is Tier 3 in this estimation because we performed a gridded spatial analysis modeling approach.

### Methodological Issues:

**Settlements remaining settlements (SL-SL)**

All carbon pools in SL-SL is assumed to be not changing thus reported as NO.

The CS values used in other categories have also been used in this category. The forest land living biomass C stocks have been taken from ENVANIS, croplands from both IPCC 2006 and neighboring countries, grasslands from Serengil et al. (2015). Thus below EFs have been used.

The CS of settlements has been calculated based on the above values (Table 6.20) in the context of the TUBITAK 112Y096 project. The following methodology has been applied;

- The study area (740 km$^2$) has been divided into 500*500 meter grids,
- The land uses in each grid have been determined from SPOT6 2013 satellite image with a 1.5*1.5 meter resolution using supervised classification,
- The accuracy check has been performed with 1000 plots with over 90 percent accuracy,
- The land use in each grid has been multiplied by carbon stocks given in Table 6.20.

- The impervious areas in each grid has been grouped under 5 classes that are >20 percent, >40 percent, >60 percent, and >80 percent. The project area has been classified for 4 settlement intensity classes in this way (Table 6.20).

**Table 6.35 Total carbon stocks calculated for various settlements intensity classes (Serengil et al., 2015)**

| Settlement class (SC) | Settlement intensity (% imperviousness) | $\bar{x}$(t C /ha) | σ(t C /ha) | Sample size (#) |
|---|---|---|---|---|
| 1 | >20 | 85.27 | 74.19 | 1 145 |
| 2 | >40 | 51.87 | 41.85 | 697 |
| 3 | >60 | 32.04 | 25.32 | 438 |
| 4 | >80 | 17.26 | 13.73 | 258 |

The weighted average for settlement land cover has been calculated as 25.17 t C/ha in total being 20.14 Mg C/ha in biomass, and 5.03 Mg C/ha in soil pools.

The settlement intensity and CS in the study are of the TUBITAK 112Y096 is given in Figure 6.19 and Figure 6.20.

**Figure 6.19 Impervious areas in the study area (Alibeyköy, Sazlıdere and Kağıthane watersheds in Istanbul)**

**Figure 6.20 Carbon intensity in the study area (Alibeyköy, Sazlıdere and Kağıthane watersheds in Istanbul)**

**Land converted to settlements (L-SL)**

*Above- and below-ground biomass*

**Table 6.36 Coefficients and living biomass CS values for L-SL subcategories**

| **Ecozones** | **Forest type** | NAI Y1 ΔCG (tC/yr/ha) | Loss Y1 ΔCL (tC/yr/ha) | BAFTER (tC/yr/ha) | BBEFORE (tC/yr/ha) | CSC Y1 (tC/ha/yr) |
|---|---|---|---|---|---|---|
| **Forest land converted to Settlements** | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 5.03 | 0 | 0 | 41.97 | -36.94 |
| | Forest Coninferous | 5.03 | 0 | 0 | 64.80 | -59.77 |
| | Forest Mixed | 5.03 | 0 | 0 | 52.35 | -47.32 |
| | Forest Degraded | 5.03 | 0 | 0 | 4.05 | 0.98 |

**Table 6.36 Coefficients and living biomass CS values for L-SL subcategories (Cont'd)**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Cropland (annual) converted to Settlements** | | | | | | |
| | $Cropland_{annual}$ | 5.03 | 0 | 0 | 5 | 0.03 |
| **Cropland (perennial) converted to Settlements** | | | | | | |
| | | 5.03 | 0 | 0 | 15 | -9.97 |
| **Grassland converted to Settlements** | | | | | | |
| | | 5.03 | 0 | 0 | 1.86 | 3.17 |
| **Wetlands converted to Settlements** | | | | | | |
| | | 5.03 | 0 | 0 | 1.86 | 3.17 |
| **Otherland converted to Settlements** | | | | | | |
| | | 5.03 | 0 | 0 | 0 | 5.03 |

*Dead organic matter*

CSC converted to settlements from forest lands are calculated based on the below coefficients and EF. The CSC for other conversions are assumed to be not occurring.

**Table 6.37 Coefficients and DOM CS values for L-SL subcategories**

| **Ecozones** | **Forest type** | CF litter | CF Dead Wood | CSC LT (tC/ha/yr) | CSC DW (tC/ha/yr) | CSC DOM (tC/ha/yr) |
|---|---|---|---|---|---|---|
| **Forest land converted to Wetland** | | | | | | |
| i.e. Mediterranean Mountain zone | Forest Deciduous | 0.37 | 0.50 | -3.09 | -0.49 | -3.58 |
| | Forest Coninferous | 0.37 | 0.50 | -7.51 | -0.36 | -7.87 |
| | Forest Mixed | 0.37 | 0.50 | -5.30 | -0.42 | -5.72 |
| | Forest Degraded | 0.37 | 0.50 | 0.00 | -0.03 | -0.03 |

*Mineral and organic soil*

The CSC in mineral soils have been calculated based on national stock values determined by General Directorate of Agricultural Research. The default conversion duration of 20 years has been applied.

**Table 6.38 Coefficients and soil CS values for L-SL subcategories**

| Ecozone | SOC ref | C stock Settl. (tC/ha) | Forest land C stock (tC/ha) | Cropland (Annual) C stock (tC/ha) | Cropland (perennial) C stock (tC/ha) | Grassland C stock (tC/ha) | Wetland C stock (tC/ha) | Otherl. C stock (tC/ha) |
|---|---|---|---|---|---|---|---|---|
| Mediterranean Mountain zone | 46.96 | 20.14 | 51.53 | 40.22 | 46.96 | 42.26 | 42.26 | 12.78 |
| Mediterranean coastal zone deciduous and coniferous forest | 37.77 | 20.14 | 46.08 | 29.62 | 37.77 | 33.99 | 33.99 | 12.78 |
| East Anatolian steppe | 47.99 | 20.14 | 48.41 | 38.90 | 47.99 | 43.19 | 43.19 | 12.78 |
| East Anatolian deciduous forest zone | 41.30 | 20.14 | 45.14 | 30.44 | 41.30 | 37.17 | 37.17 | 12.78 |
| Euxine-Colchic deciduous forest | 49.66 | 20.14 | 51.90 | 38.68 | 49.66 | 44.69 | 44.69 | 12.78 |
| Central Anatolian steppe | 40.41 | 20.14 | 49.92 | 32.14 | 40.41 | 36.37 | 36.37 | 12.78 |
| Aegean Inland deciduous and coniferous forest | 42.53 | 20.14 | 50.88 | 30.99 | 42.53 | 38.28 | 38.28 | 12.78 |
| North Anatolian deciduous, coniferous and mixed forest | 54.57 | 20.14 | 55.05 | 34.29 | 54.57 | 49.11 | 49.11 | 12.78 |

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.39 Uncertainty summary table for Settlement subcategories**

| | BY (1990) | LRY (2018) |
|---|---|---|
| Wetland Remaining Wetland | | |
| **4E1 – SL-SL** | **0%** | **0** |
| ΔCC in Living Biomass | **NA** | **NA** |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | **NA** | NA |
| Net C stock change in SOM (ΔCC) | **NA** | NA |
| Land Converted to Wetland | | |
| **4E2 – L-SL** | **0%** | 26% |
| ΔCC in Living Biomass | NA | 24% |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | NA | 97% |
| Net C stock change in SOM (ΔCC) | NA | 27% |

### Source-Specific QA/QC and Verification:

The QA/QC procedure has been realized in the framework of plan developed and carried out by TurkStat the national inventory agency. The sector specific QA/QC has been realized during the LULUCF project activities mentioned above. The calculation procedures have been checked and discussed with the LULUCF experts in and out of the agencies.

### Recalculation:

There is no recalculation for this submission in this category.

### Planned Improvement:

The planned improvements for Settlement category are;

- Update carbon stock changes for all relevant carbon pools for each land use conversion to settlements (MT, LT)
- Extent the study mentioned in methodology section to other settlement areas and thus update the CS values (MT, LT)

## 6.7. Other land (4.F)

### Source Category Description:

Other land category is a net emission due to land converted to other land. However, the amount of land converted to Other land is quite low. It is assumed that other land may have organic carbon in soils but not in living biomass.

**Information on Land Classification and Activity Data**

The area of other land category decreases during the reporting period from 1.7 Mha in 1990 to 1.3 Mha in 2018. Land conversion to other land is much lower. It has been 0.1 Mha in 2018.

### Methodological Issues:

The same conversion principles apply to Other land category. The coefficients and EFs use are as follows;

**Table 6.40 The coefficients and EF used in Other land category**

| EF | Living Biomass | DOM | Soil |
|---|---|---|---|
| Other land | 0 | 0 | 12.78 |

The C stocks for living biomass and DOM are assumed to be zero while mineral soil carbon stock is 12.78 based on calculations of General Directorate of Agricultural Research.

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.41 Uncertainty summary table for Otherland subcategories**

| | BY (1990) | LRY (2018) |
|---|---|---|
| Other land Remaining Other land | | |
| **4F1 – OL-OL** | **0%** | **0** |
| ΔCC in Living Biomass | **NA** | **NA** |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | **NA** | NA |
| Net C stock change in SOM (ΔCC) | **NA** | NA |
| Land Converted to Wetland | | |
| **4F2 – L-OL** | **0%** | 18% |
| ΔCC in Living Biomass | NA | 31% |
| Annual Loss Living Biomass (ΔCL) | NA | NA |
| Annual Gain Living Biomass (ΔCG) | NA | NA |
| Net C stock change in DOM (ΔCC) | NA | 139% |
| Net C stock change in SOM (ΔCC) | NA | 19% |

## 6.8. Direct $N_2O$ emissions from N inputs to managed soils (4(I))

### Source Category Description:

Emissions and removals from this category as not been calculated since the activity data for N inputs can not be differentiated for the sectors and land uses.

### Methodological Issues:

The NO notation key has been used for wetlands and other land. The IE notation key has been used for forest land and settlements since we presume that N inputs are common in urban areas and some specific forestry applications (i.e. nurseries) but are included in the amount used for croplands.

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.42 Uncertainty summary table for 4 (I) category**

| Summary | BY (1990) | LRY |
|---|---|---|
| Table 4(I) | 0% | 0% |

## 6.9. Emissions and removals from drainage and rewetting and other management of organic and mineral soils (4(II))

### Source Category Description:

There is no reliable data for drainage/rewetting and other management of organic and mineral soils. The category has been reported as NO.

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.43 Uncertainty summary table for 4 (II) category**

| Summary | BY (1990) | LRY |
|---|---|---|
| Table 4(II) | 0% | 0% |

## 6.10. $N_2O$ 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))

### Source Category Description:

N2O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils have been estimated and reported, according to the 2006 IPCC Guidelines, under this category. N2O emissions from land use conversions are derived from mineralization of soil organic matter resulting from the conversions that result in C losses.

### Methodological Issues:

The equation 11.8 in IPCC (2006) has been used to calculate the mineralised N resulting from loss of soil organic C stocks in mineral soils through Land-use Change or Management Practices. The emissions due to loss of soil organic C was calculated and reported for all conversions. Gains have not been calculated since IPCC 2006 Guidelines suggest Tier 3 methods in order to calculate gains.

A default value of 15 as the C:N ratio of the soil organic matter has been used for conversions involving land-use change from forest or grassland to cropland. A default value of 10 has been used for conversions or management changes on cropland remaining cropland.

The parameters used in calculations are;

**Table 6.44 EFs used for $N_2O$ emissions**

| **Parameter (for 1 tC lost)** | **C/N=15 (all)** | **C/N=10 (CL)** |
|---|---|---|
| C/N ratio | 15 | 10 |
| EF1 (kgN2O-N/kg N ) | 0.01 | 0.01 |
| Factor (N2O-N) to (N2O) | 1.57 | 1.57 |
| **Aggregated factor (t N2O)** | **0.001047619** | **0.001571429** |

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.45 Uncertainty summary table for 4 (III) category**

| Summary | BY (1990) | LRY |
|---|---|---|
| Table 4(I) | 0% | 75% |

### Recalculation:

There is no recalculation for this submission in this category.

## 6.11. Indirect $N_2O$ emissions from managed soils (4(IV))

### Source Category Description:

The estimation of indirect N2O emissions follows the 2006 IPCC guidelines (Volume 4, Ch. 11). The indirect N2O emissions from N leaching and runoff from managed soils are estimated based on annual amount of N mineralised in mineral soils associated with loss of soil organic matter due to land-use change (i.e. from direct N2O emissions). Default emission factors have been used accordingly.

Reference to 2006 IPCC equation: Vol. 4., Ch. 11: 11.10

### Methodological Issues:

The atmospheric deposition as indirect N2O Emissions from Managed Soils has been reported as IE in this category as sources of N can not be differentiated from Croplands and Grasslands thus reported under 3D(b). However, Nitrogen Leaching and Runoff has been estimated by using the default EFs of IPCC 2006.

**Table 6.46 EFs used for $N_2O$ emissions**

| Parameter | Values |
|---|---|
| Volatilization fraction: Frac GASF ((kg NH3–N + NOx–N) (kg Napplied) –1) | 0.2 |
| EF4 (kg N2O–N (kg NH3–N + NOX–Nvolatilised)-1) | 0.01 |
| | |
| FracLEACH-(H) [N losses by leaching/runoff for regions | 0.3 |
| EF5 [leaching/runoff], kg N2O–N (kg N leaching/runoff) | 0.0075 |

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.47 Uncertainty summary table for 4 (IV) category**

| Summary | BY (1990) | LRY |
|---|---|---|
| Table 4(I) | 0% | 387% |

### Recalculation:

There is no recalculation for this submission in this category.

## 6.12. Biomass Burning (4(V))

### Source Category Description:

Several types of country-specific data have been collected to estimate emissions from biomass burning. The most important input variable is activity data (i.e. area burnt) that is collected each year. The second important variable to be collected is above-ground biomass of lands that were affected by wildfires. In addition, Turkey also collects country-specific data on types of wildfires, carbon pools affected and the fraction of biomass lost in wildfires.

**Methodological Issues:**

To calculate emissions from wildfires;

- Average above-ground biomass of those forest types (coniferous, deciduous, mixed and OFL) that were affected by wildfires were calculated on an annual basis.
- Average fraction of biomass lost in wildfires was estimated.

Emission estimation due to biomass burning follows the 2006 IPCC guidelines (Volume 4, Ch. 2 and Ch. 4). Currently, CO2 emissions from biomass burning are estimated as part of annual carbon loss in biomass (i.e. Ldisturbance). A generic approach for estimating the amount of carbon lost from disturbances is applied, based on area affected by disturbance (i.e. area burnt), average above-ground biomass on area burnt and average fraction of biomass lost in wildfires. Non-CO2 emissions from biomass burning have also been estimated by applying a generic methodology for each of individual greenhouse gases through use of default emission factors (i.e. for CO, $CH_4$, $N_2O$, NOx and NMVOC).

Field burning of agricultural residues are estimated under the Agriculture sector (CRF table 3.F).

Controlled burning is not a practice used in Turkey. Thus reported as NO. Emissions from FL-FL and L-FL subcategories have been estimated. Other categories have been reported as NE as there is no available activity data.

Reference to the 2006 IPCC equations: Vol. 4., Ch. 2: 2.14 / 2.27

The EFs and coefficients used are as follows;

**Table 6.48 EFs used for Biomass burning emissions**

| Parameters | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1990 | 1995 | 2000 | 2005 | 2010 | 2015 | 2018 |
| ABG Dec (tDM/ha) | 98.50 | 102.49 | 107.61 | 127.34 | 128.00 | 112.87 | 106.88 |
| ABG Con (tDM/ha) | 71.09 | 73.98 | 77.67 | 83.75 | 86.12 | 85.79 | 87.88 |
| ABG Mixed (tDM/ha) | 84.80 | 88.23 | 92.64 | 105.55 | 107.06 | 99.33 | 97.38 |
| ABG Degraded (tDM/ha) | 5.78 | 6.02 | 6.32 | 6.52 | 5.57 | 4.64 | 4.19 |
| R For Dec | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| R For Con | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 | 0.29 |
| R For Mix | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 | 0.26 |
| R For Deg | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 | 0.43 |
| LB total Dec (tDM/ha) | 127.07 | 132.22 | 138.82 | 164.27 | 165.12 | 145.60 | 137.88 |
| LB total Con (tDM/ha) | 87.45 | 90.99 | 95.53 | 103.01 | 105.93 | 105.53 | 108.09 |
| LB total Mixed (tDM/ha) | 106.84 | 111.18 | 116.73 | 132.99 | 134.90 | 125.16 | 122.70 |
| LB total Degraded (tDM/ha) | 8.27 | 8.60 | 9.03 | 9.32 | 7.96 | 6.64 | 5.99 |
| LT Dec (tDM/ha) | 8.35 | 8.35 | 8.35 | 8.35 | 8.35 | 8.35 | 8.35 |
| LT Con (tDM/ha) | 20.30 | 20.30 | 20.30 | 20.30 | 20.30 | 20.30 | 20.30 |
| LT Mix (tDM/ha) | 14.32 | 14.32 | 14.32 | 14.32 | 14.32 | 14.32 | 14.32 |
| LT Deg (tDM/ha) | 0.00 | 5.00 | 10.00 | 15.00 | 20.00 | 25.00 | 27.00 |
| DW Dec (tDM/ha) | 0.99 | 1.02 | 1.08 | 1.27 | 1.28 | 1.13 | 1.07 |
| DW Con (tDM/ha) | 0.71 | 0.74 | 0.78 | 0.84 | 0.86 | 0.86 | 0.88 |
| DW Mix (tDM/ha) | 0.85 | 0.88 | 0.93 | 1.06 | 1.07 | 0.99 | 0.97 |
| DW Deg (tDM/ha) | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 | 0.05 | 0.04 |
| Burned share Dec | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Burned share Con | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 |

**Table 6.48 EFs used for Biomass burning emissions (Cont'd)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Burned share Mix | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| Burned share Deg | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total stock available for burning (tDM/ha) | 105.00 | 109.35 | 115.03 | 129.25 | 132.07 | 125.52 | 125.41 |
| Cf (combustion factor, Extra tropical forest) | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 | 0.44 |
| FLremFL Amount burnt (tDM/ha) | 46.20 | 48.11 | 50.61 | 56.87 | 58.11 | 55.23 | 55.18 |
| convFL Amount burnt (tDM/ha) | 11.11 | 8.11 | 8.11 | 8.11 | 8.11 | 7.96 | 7.96 |

### Uncertainties and Time-Series Consistency:

The time series consistency has been ensured via the new land tracking system as explained in section 6.3.

The same methodology to estimate uncertainty has been employed as 6.4.5 and the below summary table has been produced.

**Table 6.49 Uncertainty summary table for 4 (V) category**

| Summary | BY (1990) | LRY |
|---|---|---|
| Table 4(I) | 54% | 54% |

### Recalculation:

There is no recalculation for this submission in this category.

## 6.13. Harvested Wood Products (4.G)

### Source Category Description:

Carbon stock changes of the HWP category calculations have been revised and recalculated in this submission. The previous computation was done in the context of a study by Bouyer and Serengil (2014). The revision involved below changes;

- The approach has been reviewed by international experts and modified based on their suggestions,
- Paper was added as the third product,
- A KP analogical approach has been employed. Export and import amounts have been taken into account,

**Figure 6.21 Emissions and removals in HWP pool**

### Methodological Issues:

The following methodology has been applied in calculations;

The activity data on various forest products (sawnwood, wood panels and paper) variables for HWP has been downloaded from the FAO database: http://www.fao.org/faostat/en/#data/FO. It is assumed that paperboard is part of the paper category. The data on production of industrial roundwood (production, import, export) and production of wood pulp (production, import, export) have been obtained from FAO database and annual fraction (i.e. share) of domestic harvest calculated accordingly.

The Approach B has been used for HWP calculations. General method to estimate annual change in carbon stock in "products in use" based on first order decay function and half-life is used. Domestic consumption is computed from production data (domestic harvest) plus imports minus exports. The annual fraction of the feedstock coming from domestic harvest for the HWP categories sawnwood and wood-based panels has been estimated. Also the annual fraction of domestically produced wood pulp as feedstock originating from domestic harvest for the production of the HWP category paper and paperboard (IPCC 2014) is estimated.

Annual carbon stock inflow from domestic wood production for each category was extrapolated backward by applying equation 12.6 to get figures for period before 1961, because FAO statistics start from 1961 (annual rate of increase for industrial roundwood production can be used from table 12.3; for Europe the U value = 0.0151).

Country specific wood density values have been used.

Reference to 2014 IPCC equations: Ch. 2: 2.8.1 / 2.8.2
Reference to 2014 IPCC table: Ch. 2: 2.8.1
Reference to 2006 IPCC equation: Vol. 4., Ch. 12: 12.6

Default half-lives from Table 2.8.2 were used for each HWP category in the FOD constant (k) and the estimation from the year 1900 to present has been performed. Annual CSC in the HWP pool was calculated as difference between subsequent year for the whole reporting period, i.e. base year to present ($\Delta Ci = Ci - Ci\text{-}1$).

Reference to 2006 IPCC equation: Vol. 4., Ch. 12: 12.1
Reference to 2014 IPCC table: Ch. 2: 2.8.2

### Recalculation:

There is no recalculation for this submission in this category.

# 7. WASTE (CRF SECTOR 5)

## 7.1. Sector Overview

The waste sector includes $CH_4$ emissions from solid waste disposal, $CH_4$ and $N_2O$ emissions from biological treatment of solid waste, $CO_2$, $CH_4$ and $N_2O$ emissions from open burning of waste and, $CH_4$ and $N_2O$ emissions from wastewater treatment and discharge. Emissions from waste incineration are included in the inventory but reported in the energy sector since the purpose of waste incineration is energy recovery.

Total waste emissions for the year 2018 are 17.8 Mt $CO_2$ eq., or 3.4% of total GHG emissions (without LULUCF). Within the sector, 50.0% of the emissions were from wastewater treatment and discharge, followed by 49.9% from solid waste disposal, 0.12% from biological treatment of solid waste and 0.01% from open burning of waste.

The major GHG emissions from the waste sector are $CH_4$ emissions, which represent 65.7% of total emissions from this sector in 2018, followed by $N_2O$ emissions with 34.3% and a very small percent of $CO_2$ as 0.01%.

**Table 7.1 $CO_2$ equivalent emissions for the waste sector, 2018**

**(kt $CO_2$ eq.)**

| GHG source and sink categories | $CO_2$ | $CH_4$ | $N_2O$ | Total |
|---|---|---|---|---|
| **5. Waste** | 1.2 | 11 662.9 | 6 099.7 | 17 763.9 |
| A. Solid waste disposal | NA | 8 863.9 | NA | 8 863.9 |
| B. Biological treatment of solid waste | NA | 11.9 | 8.5 | 20.5 |
| C. Incineration and open burning of waste | 1.2 | 1.0 | 0.2 | 2.4 |
| D. Wastewater treatment and discharge | NA | 2 786.1 | 6 091.0 | 8 877.1 |
| E. Other | NO | NO | NO | NO |

Waste emissions are 60.3% (6.7 Mt $CO_2$ eq.) higher in 2018 than they were in 1990 and 2.1% (0.37 Mt $CO_2$ eq.) higher than in 2017 as seen in Figure 7.1.

**Figure 7.1 Total GHG emissions of waste sector, 1990-2018**

Total emissions in the waste sector gradually increased between 1990 (11 081 kt $CO_2$ eq.) and 2018 (17 764 kt $CO_2$ eq.) driven largely by the steady rise in emissions from solid waste disposal between 1990 and 2011 followed by a decrease in emissions since from solid waste disposal after 2011. Emissions from solid waste disposal increased by 78.4% (8 684 kt $CO_2$ eq.) between 1990 and 2011, before decreasing by 10.1% between 2011 and 2018 (2 000 kt $CO_2$ eq.), except an increase with 3.6% (653 kt $CO_2$ eq.) between 2013 and 2015 and 2.1% (368 kt $CO_2$ eq.) between 2017 and 2018.

Methane recovery in solid waste disposal sites is reported as of 2002 (37 kt $CO_2$ eq.) and increasing to 8 824 kt $CO_2$ eq. in 2018. The decline in recent total emissions is mainly due to the increase in methane recovery between 2011 (1 418 kt $CO_2$ eq.) and 2013 (3 993 kt $CO_2$ eq.), an increase of 181.6%. There is also an increasing trend in methane recovery with 48.7% from 2013 to 2016, with a significant increase of 48.6% between 2016 and 2018.

For the full discussion of trends for individual categories, see the category-specific discussions below.

Methodological tiers and EFs used to estimate emissions from waste sector are summarized by categories in Table 7.2.

**Table 7.2 Summary of methods and emission factors used**

| GHG source and sink categories | $CO_2$ | | $CH_4$ | | $N_2O$ | |
|---|---|---|---|---|---|---|
| | Method applied | Emission factor | Method applied | Emission factor | Method applied | Emission factor |
| **5. Waste** | T2 | CS,D | T1,T2 | CS,D | T1 | D |
| A. Solid waste disposal | NA | NA | T2 | CS,D | NA | NA |
| B. Biological treatment of solid waste | NA | NA | T1 | D | T1 | D |
| C. Incineration and open burning of waste | T2 | CS,D | T1 | D | T1 | D |
| D. Wastewater treatment and discharge | NA | NA | T2 | CS | T1 | D |

D: IPCC Default, CS: Country Specific, NA: Not Applicable, T1: Tier 1, T2: Tier 2

## 7.2. Solid Waste Disposal (Category 5.A)

### Source Category Description:

This category includes emissions from solid waste disposal sites (SWDS). The category consists of two waste disposal practices in Turkey:

- Managed waste disposal sites,
- Unmanaged waste disposal sites.

There are no semi-aerobic managed waste disposal sites (5.A.1.b) in Turkey and all managed waste disposal sites are categorized under anaerobic managed waste disposal sites (5.A.1.a). Unmanaged waste disposal sites (5.A.2) cannot be classified into deep and shallow due to lack of knowledge. The category covers $CH_4$ emissions from two types of waste in municipal SWDS in Turkey:

- Municipal solid waste (MSW),
- Industrial waste,
- Sewage sludge, and
- Clinical waste.

According to the clinical waste management practices and regulations in Turkey, clinical waste which is collected separately from health institutions is disposed of in SWDS or incinerated. Almost all of the clinical waste is sterilized prior to disposal in SWDS. $CH_4$ emissions from clinical waste which is collected separately are assumed to be negligible and have not been reported so far. Based on the ERT findings in the latest review, clinical waste emissions were estimated and reported in this submission. Likewise, the ongoing study to determine the amount of sewage sludge disposed in SWDS from the results of

Municipal Wastewater Statistics of Turkish Statistical Institute (TurkStat) have been completed and the emission estimates done for the whole time series. Hazardous wastes are disposed in separated lots in SWDS. Hazardous wastes are not taken into account in this source category because these types of wastes are not producing methane. Industrial waste including hazardous and clinical waste is usually incinerated and considered in the category of Public Electricity and Heat Production (1.A.1.a).

The total amount of waste disposed in the SWDS has increased through the years mainly due to population growth (Table 7.7). The number of managed SWDS has also increased over the years (Table 7.4) and the share of managed SWDS as a fraction of total SWDS surpassed unmanaged SWDS as of from 2012 onwards, particularly due to improved landfill management practices, including landfill gas recovery.

Since 2004, Turkey has carried out many actions related to waste management and regulatory policies. The first legal regulation in this field in Turkey was the Solid Waste Control Regulation (14.03.1991) which provided for and guided practices in the collection and removal of domestic and industrial waste. Revisions of the regulation to harmonize it with the EU Landfill policy were carried out in 2010 (26.03.2010). Solid Waste Management Action Plan covering 2008-2012 was prepared by the former Ministry of Environment and Forestry (MoEF), using the outcomes of the EU funded Environmental Heavy Cost Investment Planning (EHCIP) Project, solid waste master plan projects and the EU Integrated Environmental Adaptation Strategy (NES) (2007-2023). All these waste management policies and actions in Turkey are expected to reduce the share of GHG emissions from the waste sector.

### Methodological Issues:

**Methane Emissions from Solid Waste Disposal**

$CH_4$ emissions from solid waste disposal is a key category according to both a level and a trend assessment. $CH_4$ emissions of MSW, industrial waste, sewage sludge and clinical waste emissions are estimated from municipal SWDS in Turkey. The IPCC T2 First Order Decay (FOD) method recommended in the 2006 IPCC Guidelines for National GHG Inventories is used with default parameters and country-specific AD on current and historical waste disposal at SWDS to estimate $CH_4$ emissions. Closed SWDS continue to emit $CH_4$. This is automatically accounted for in the FOD method because historical waste disposal data are used. The $CH_4$ emissions from solid waste disposal for a single year can be estimated based on *Equation 3.1 in 2006 IPCC, Volume 5, Chapter 3* as given in the equation below.

$$CH_4\ Emissions = \left[\sum_x CH_4 generated_{x,T} - R_T\right] \bullet (1 - OX_T)$$

Where:

$CH_4$ Emissions = $CH_4$ emitted in year *T*, Gg

T = inventory year

x = waste category or type/material

$R_T$ = recovered $CH_4$ in year *T*, Gg

$OX_T$ = oxidation factor in year *T*, (fraction)

The $CH_4$ generated by each category of waste disposed is added to get total $CH_4$ generated in each year. Finally, emissions of $CH_4$ are calculated by subtracting the $CH_4$ gas recovered from the disposal site.

The total amount of $CH_4$ generated, $CH_4$ recovered and net $CH_4$ emissions from solid waste disposal sites are estimated as given in Table 7.3 and Figure 7.2.

**Table 7.3 $CH_4$ generated, recovered and emitted from SWDS, 1990-2018**

**(kt)**

| Year | $CH_4$ Generated | $CH_4$ Recovered | | $CH_4$ Emitted | |
|---|---|---|---|---|---|
| | | Managed | Unmanaged | Managed | Unmanaged |
| 1990 | 269.2 | NO | NO | NO | 269.2 |
| 1991 | 275.7 | NO | NO | NO | 275.7 |
| 1992 | 282.4 | NO | NO | NO | 282.4 |
| 1993 | 290.0 | NO | NO | 2.2 | 287.8 |
| 1994 | 297.8 | NO | NO | 4.0 | 293.7 |
| 1995 | 305.1 | NO | NO | 5.6 | 299.5 |
| 1996 | 317.1 | NO | NO | 8.6 | 308.5 |
| 1997 | 331.6 | NO | NO | 14.5 | 317.1 |
| 1998 | 348.5 | NO | NO | 23.5 | 325.0 |
| 1999 | 366.5 | NO | NO | 33.9 | 332.6 |
| 2000 | 383.3 | NO | NO | 45.9 | 337.3 |
| 2001 | 400.7 | NO | NO | 59.5 | 341.2 |
| 2002 | 418.7 | 1.5 | NO | 72.9 | 344.2 |
| 2003 | 434.6 | 2.5 | NO | 83.3 | 348.8 |
| 2004 | 450.9 | 2.3 | NO | 95.0 | 353.5 |
| 2005 | 464.1 | 1.7 | NO | 105.5 | 357.0 |
| 2006 | 478.8 | 2.2 | NO | 114.5 | 362.2 |
| 2007 | 493.1 | 8.3 | NO | 122.2 | 362.6 |
| 2008 | 508.6 | 21.4 | NO | 124.0 | 363.2 |
| 2009 | 522.2 | 36.5 | NO | 124.9 | 360.8 |
| 2010 | 538.8 | 47.9 | NO | 131.5 | 359.4 |
| 2011 | 555.0 | 56.7 | NO | 143.1 | 355.3 |
| 2012 | 574.9 | 96.2 | NO | 126.1 | 352.7 |
| 2013 | 594.5 | 150.9 | 8.8 | 95.2 | 339.6 |
| 2014 | 613.5 | 171.8 | 8.0 | 99.3 | 334.3 |
| 2015 | 633.9 | 176.6 | 8.0 | 119.3 | 330.0 |
| 2016 | 656.6 | 231.5 | 6.0 | 92.1 | 327.0 |
| 2017 | 683.1 | 305.6 | 15.8 | 48.3 | 313.4 |
| 2018 | 707.5 | 340.0 | 13.0 | 43.3 | 311.2 |

**Figure 7.2 $CH_4$ emissions from solid waste disposal, 1990-2018**

In Turkey, due to the increased capacity and number of the methane recovery plants producing electrical or thermal energy from the waste gas, net emissions and methane recovery amounts are approaching one another.

**Choice of Activity Data**

For calculating $CH_4$ generated; municipal solid waste AD, industrial waste AD, sewage sludge AD and clinical waste AD are needed. As is described in more detail below, for MSW, industrial waste, sewage sludge and clinical waste, national data are used where possible, depending on availability of all ADs. If national data are not available for a specific inventory year, population data and waste per capita data are used to estimate national data on MSW generation. By the same logic, GDP data and waste generation rate data are used as drivers for estimating industrial waste generation and some missing data imputation methods were implied for sludge and clinical waste data when any year's data is missing.

The percentage of waste generated which goes to SWDS (% to SWDS) and composition of waste going to SWDS are also used for the calculations.

The distribution of site types is used for calculating a weighted average methane correction factor (MCF). The other parameters needed for the FOD model are; degradable organic carbon (DOC), fraction of DOC which decomposes ($DOC_F$), methane generation rate constant (k), fraction of methane (F) and oxidation factor (OX).

The justification for the selection of parameters by Turkey is further described below.

**Municipal Solid Waste Activity Data**

The annual data of MSW disposed in the municipal SWDS (the amount of MSW both in managed and unmanaged landfills) are collected by TurkStat from *Municipal Waste Statistics Survey* which is applied to all municipalities. However, the survey could not be conducted on a regular basis before 2006, and since 2006 has started to be held biennially. The data for years 1994-1998, 2001-2004, 2006, 2008, 2010, 2012, 2014, 2016 and 2018 are available. The specific data collected by TurkStat are the amount of MSW is weighed, generally based on waste delivery vehicle capacity. 2005 data of MSW disposed in managed SWDS is gathered via *Waste Disposal and Recovery Facilities Statistics Survey* by TurkStat. In Turkey, managed SWDS are in operation since 1992 (See Table 7.4). In 1992 and 1993, there was only one managed SWDS according to the results of *Municipal Waste Statistics Survey*. Therefore, the waste disposal amounts of that site for those years are used for emission estimations (see Table 7.6). Missing data for the years not surveyed for total MSW delivered to SWDS are estimated by regression model. For distribution of MSW to managed and unmanaged landfills between 1990 and 2018, the missing data for the remaining years are estimated by linear interpolation. 2017 data of MSW disposed in managed SWDS has been recalculated by linear interpolation in the 2020 inventory submission due to the availability of 2018 survey data.

Data are generally available from the statistical surveys described above (noting the need to resolving data gaps for intervening years when survey data were not available). Data on MSW generation were not available prior to 1994. Recognizing that, in accordance with the 2006 IPCC Guidelines, data on MSW generation are needed for at least the last 50 years, Turkey has made assumptions to collect the full time series of data. As described further below, between 1950 and 1993, the amount of waste generated is estimated based on the waste per capita ratio in 1994 and mid-year population data for each year.

The total number of managed SWDS has increased by years as shown in Table 7.4 below.

**Table 7.4 Number of managed SWDS, 1992-2018**

| 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 6 | 6 | 8 | 8 | 10 | 12 | 12 |
| **2003** | **2004** | **2005** | **2006** | **2008** | **2010** | **2012** | **2014** | **2016** | **2018** |
| 15 | 16 | 18 | 22 | 37 | 52 | 80 | 113 | 134 | 159 |

Source: (1) TurkStat, Municipal Waste Statistics, 1992-2010
(2) TurkStat, Waste Disposal and Recovery Facilities Statistics, 2012-2018

Amount of municipal waste by disposal methods are given in Table 7.5.

**Table 7.5 Amount of municipal waste by disposal methods, 1994-2018**

(kt)

| Year | Municipality's dumping site | Controlled landfill site | Composting plant | Burning in an open area | Lake and river disposal | Burial | Other (1) |
|---|---|---|---|---|---|---|---|
| 1994 | 14 479.2 | 809.0 | 192.1 | 442.1 | 557.6 | 523.4 | 753.3 |
| 1995 | 17 174.9 | 1 444.0 | 158.9 | 405.0 | 370.4 | 828.9 | 527.3 |
| 1996 | 17 519.5 | 2 847.0 | 178.8 | 437.9 | 370.3 | 823.6 | 303.3 |
| 1997 | 16 805.1 | 4 363.8 | 180.4 | 625.1 | 384.4 | 1 446.9 | 365.8 |
| 1998 | 16 852.8 | 5 257.9 | 166.3 | 386.1 | 374.9 | 852.4 | 1 039.1 |
| 2001 | 14 569.8 | 8 304.2 | 218.1 | 343.6 | 100.9 | 481.7 | 1 115.4 |
| 2002 | 16 310.0 | 7 047.0 | 383.1 | 220.5 | 196.8 | 499.9 | 715.8 |
| 2003 | 16 566.5 | 7 431.8 | 325.9 | 258.5 | 228.5 | 597.0 | 709.3 |
| 2004 | 16 415.8 | 7 001.5 | 350.7 | 101.6 | 154.7 | 426.5 | 562.7 |
| 2006 | 14 941.2 | 9 428.3 | 254.9 | 246.5 | 69.8 | 144.5 | 194.7 |
| 2008 | 12 677.1 | 10 947.4 | 275.7 | 239.3 | 47.7 | 100.5 | 73.1 |
| 2010 | 11 001.2 | 13 746.9 | 194.5 | 133.9 | 44.0 | 34.3 | 122.1 |
| 2012 | 9 771.0 | 15 484.2 | 154.7 | 104.8 | 33.4 | 94.3 | 202.3 |
| 2014 | 9 935.6 | 17 807.4 | 126.5 | 4.3 | 15.8 | 7.3 | 113.8 |
| 2016 | 9 094.9 | 19 337.9 | 146.5 | 10.2 | 0.5 | 6.7 | 41.1 |
| 2018 | 6 520.7 | 21 643.8 | 122.9 | 6.1 | 0.5 | 2.0 | 65.3 |

Source: TurkStat, Municipal Waste Statistics

(1) Data refers to disposals by using as filling material and dumping onto land.

The amount of waste disposed in unmanaged SWDS consists of the amount of waste disposed to municipality's dumping sites, burial and other.

Annual municipal solid waste at the SWDS and distribution of waste by waste management type are given in Table 7.6.

**Table 7.6 Annual MSW and distribution of waste by management type, 1990-2018**

| | Annual MSW at the SWDS (kt) | | | Distribution of waste (%) | |
|---|---|---|---|---|---|
| **Year** | **Total** | **Managed** | **Unmanaged** | **Managed** | **Unmanaged** |
| 1990 | 15 518.4 | NO | 15 518.4 | 0.0 | 100.0 |
| 1991 | 15 781.6 | NO | 15 781.6 | 0.0 | 100.0 |
| 1992 | 16 043.7 | 986.1 | 15 057.6 | 6.1 | 93.9 |
| 1993 | 16 304.7 | 827.2 | 15 477.5 | 5.1 | 94.9 |
| 1994 | 16 564.8 | 809.0 | 15 755.8 | 4.9 | 95.1 |
| 1995 | 19 975.1 | 1 444.0 | 18 531.1 | 7.2 | 92.8 |
| 1996 | 21 493.5 | 2 847.0 | 18 646.4 | 13.2 | 86.8 |
| 1997 | 22 981.5 | 4 363.8 | 18 617.7 | 19.0 | 81.0 |
| 1998 | 24 002.3 | 5 257.9 | 18 744.3 | 21.9 | 78.1 |
| 1999 | 23 256.9 | 6 273.3 | 16 983.5 | 27.0 | 73.0 |
| 2000 | 23 894.1 | 7 288.8 | 16 605.3 | 30.5 | 69.5 |
| 2001 | 24 471.1 | 8 304.2 | 16 166.9 | 33.9 | 66.1 |
| 2002 | 24 572.6 | 7 047.0 | 17 525.7 | 28.7 | 71.3 |
| 2003 | 25 304.6 | 7 431.8 | 17 872.8 | 29.4 | 70.6 |
| 2004 | 24 406.4 | 7 001.5 | 17 404.9 | 28.7 | 71.3 |
| 2005 | 25 947.4 | 7 078.2 | 18 869.2 | 27.3 | 72.7 |
| 2006 | 24 708.7 | 9 428.3 | 15 280.3 | 38.2 | 61.8 |
| 2007 | 25 484.4 | 10 187.9 | 15 296.5 | 40.0 | 60.0 |
| 2008 | 23 798.2 | 10 947.4 | 12 850.7 | 46.0 | 54.0 |
| 2009 | 25 700.0 | 12 347.2 | 13 352.8 | 48.0 | 52.0 |
| 2010 | 24 904.4 | 13 746.9 | 11 157.5 | 55.2 | 44.8 |
| 2011 | 26 319.0 | 14 615.5 | 11 703.5 | 55.5 | 44.5 |
| 2012 | 25 551.8 | 15 484.2 | 10 067.6 | 60.6 | 39.4 |
| 2013 | 25 267.0 | 16 645.8 | 8 621.2 | 65.9 | 34.1 |
| 2014 | 27 864.2 | 17 807.4 | 10 056.8 | 63.9 | 36.1 |
| 2015 | 27 415.0 | 18 572.7 | 8 842.3 | 67.7 | 32.3 |
| 2016 | 28 480.5 | 19 337.9 | 9 142.6 | 67.9 | 32.1 |
| 2017 | 28 837.0 | 20 490.9 | 8 346.1 | 71.1 | 28.9 |
| 2018 | 28 231.7 | 21 643.8 | 6 587.9 | 76.7 | 23.3 |

***Population Data:*** Historical data are obtained from TurkStat's *Mid-year Population Estimations and Projections* from 1950 onwards as given in Table 7.7. Population estimations are based on General Population Census until 1985. Estimations and projections for the mid-year population size for the 1986-1999 period are based on 2008 Address Based Population Registration System (ABPRS) with Health Surveys and estimations and projections after 2000 are based on 2012 ABPRS and the other administrative sources. Between the years 2007-2018, the annual results of ABPRS are used.

**Table 7.7 Mid-year population, 1950-2018**

| Year | Population | Year | Population |
|---|---|---|---|
| 1950 | 20 807 000 | 1985 | 50 307 000 |
| 1951 | 21 351 000 | 1986 | 51 480 000 |
| 1952 | 21 952 000 | 1987 | 52 370 000 |
| 1953 | 22 569 000 | 1988 | 53 268 000 |
| 1954 | 23 204 000 | 1989 | 54 192 000 |
| 1955 | 23 857 000 | 1990 | 55 120 000 |
| 1956 | 24 540 000 | 1991 | 56 055 000 |
| 1957 | 25 250 000 | 1992 | 56 986 000 |
| 1958 | 25 981 000 | 1993 | 57 913 000 |
| 1959 | 26 733 000 | 1994 | 58 837 000 |
| 1960 | 27 506 000 | 1995 | 59 756 000 |
| 1961 | 28 227 000 | 1996 | 60 671 000 |
| 1962 | 28 931 000 | 1997 | 61 582 000 |
| 1963 | 29 652 000 | 1998 | 62 464 000 |
| 1964 | 30 391 000 | 1999 | 63 364 000 |
| 1965 | 31 149 000 | 2000 | 64 269 000 |
| 1966 | 31 936 000 | 2001 | 65 166 000 |
| 1967 | 32 750 000 | 2002 | 66 003 000 |
| 1968 | 33 586 000 | 2003 | 66 795 000 |
| 1969 | 34 443 000 | 2004 | 67 599 000 |
| 1970 | 35 321 000 | 2005 | 68 435 000 |
| 1971 | 36 215 000 | 2006 | 69 295 000 |
| 1972 | 37 133 000 | 2007 | 70 158 000 |
| 1973 | 38 073 000 | 2008 | 71 052 000 |
| 1974 | 39 037 000 | 2009 | 72 039 000 |
| 1975 | 40 026 000 | 2010 | 73 142 000 |
| 1976 | 40 916 000 | 2011 | 74 224 000 |
| 1977 | 41 769 000 | 2012 | 75 176 000 |
| 1978 | 42 641 000 | 2013 | 76 148 000 |
| 1979 | 43 531 000 | 2014 | 77 182 000 |
| 1980 | 44 439 000 | 2015 | 78 218 000 |
| 1981 | 45 540 000 | 2016 | 79 278 000 |
| 1982 | 46 688 000 | 2017 | 80 313 000 |
| 1983 | 47 864 000 | 2018 | 81 407 000 |
| 1984 | 49 070 000 | | |

Source: TurkStat, Mid-year Population Estimations and Projections

***Waste Per Capita:*** To calculate waste per capita (kg/cap/yr), the amount of MSW generated and mid-year population data are used. The amount of MSW generated for the surveyed years (1994-1998, 2001-2004, 2006, 2008, 2010, 2012, 2014, 2016 and 2018) are obtained from TurkStat's *Municipal Waste Statistics.* The estimations of TurkStat are used for the years 1999, 2000, 2005, 2007, 2009, 2011, 2013, 2015 and 2017. Due to lack of historical MSW generated data, the waste per capita of 1994 (398.5 kg/cap/yr) is used for 1950-1993.

**Table 7.8 Waste per capita, 1990-2018**

| Year | MSW Generated (kt) | Population (millions) | Waste per capita (kg/cap/yr) |
|---|---|---|---|
| 1990 | 21 966.7 | 55.1 | 398.5 |
| 1991 | 22 339.3 | 56.1 | 398.5 |
| 1992 | 22 710.3 | 57.0 | 398.5 |
| 1993 | 23 079.8 | 57.9 | 398.5 |
| 1994 | 23 448.0 | 58.8 | 398.5 |
| 1995 | 27 234.1 | 59.8 | 455.8 |
| 1996 | 29 348.0 | 60.7 | 483.7 |
| 1997 | 31 943.8 | 61.6 | 518.7 |
| 1998 | 32 972.9 | 62.5 | 527.9 |
| 1999 | 30 470.0 | 63.4 | 480.9 |
| 2000 | 30 617.0 | 64.3 | 476.4 |
| 2001 | 31 030.9 | 65.2 | 476.2 |
| 2002 | 30 999.3 | 66.0 | 469.7 |
| 2003 | 31 081.4 | 66.8 | 465.3 |
| 2004 | 29 736.2 | 67.6 | 439.9 |
| 2005 | 31 351.9 | 68.4 | 458.1 |
| 2006 | 30 081.8 | 69.3 | 434.1 |
| 2007 | 30 365.6 | 70.2 | 432.8 |
| 2008 | 28 454.0 | 71.1 | 400.5 |
| 2009 | 30 196.0 | 72.0 | 419.2 |
| 2010 | 29 733.0 | 73.1 | 406.5 |
| 2011 | 30 862.0 | 74.2 | 415.8 |
| 2012 | 30 786.0 | 75.2 | 409.5 |
| 2013 | 30 920.0 | 76.1 | 406.1 |
| 2014 | 31 230.0 | 77.2 | 404.6 |
| 2015 | 31 283.0 | 78.2 | 399.9 |
| 2016 | 33 763.5 | 79.3 | 425.9 |
| 2017 | 34 173.0 | 80.3 | 425.5 |
| 2018 | 34 532.6 | 81.4 | 424.2 |

***% to SWDS:*** To calculate percentage of MSW generated which goes to SWDS, the amount of MSW generated and MSW landfilled data are used. The amount of MSW landfilled for the surveyed years (1994-1998, 2001-2004, 2006, 2008, 2010, 2012, 2014, 2016 and 2018) are obtained from TurkStat's *Municipal Waste Statistics Survey.* The estimations of TurkStat are used for the years 1999, 2000, 2005, 2007, 2009, 2011, 2013, 2015 and 2017. Due to lack of MSW generated data, % to SWDS of 1994 (70.6%) is used for 1950-1993.

% to SWDS obtained by dividing the amount of MSW landfilled by MSW generated are given for 1990-2018 in Table 7.9.

**Table 7.9 Percentage of MSW disposed in the SWDS, 1990-2018**

| Year | MSW Generated (kt) | MSW Landfilled (kt) | % to SWDS (%) |
|---|---|---|---|
| 1990 | 21 966.7 | 15 518.4 | 70.6 |
| 1991 | 22 339.3 | 15 781.6 | 70.6 |
| 1992 | 22 710.3 | 16 043.7 | 70.6 |
| 1993 | 23 079.8 | 16 304.7 | 70.6 |
| 1994 | 23 448.0 | 16 564.8 | 70.6 |
| 1995 | 27 234.1 | 19 975.1 | 73.3 |
| 1996 | 29 348.0 | 21 493.5 | 73.2 |
| 1997 | 31 943.8 | 22 981.5 | 71.9 |
| 1998 | 32 972.9 | 24 002.3 | 72.8 |
| 1999 | 30 470.0 | 23 256.9 | 76.3 |
| 2000 | 30 617.0 | 23 894.1 | 78.0 |
| 2001 | 31 030.9 | 24 471.1 | 78.9 |
| 2002 | 30 999.3 | 24 572.6 | 79.3 |
| 2003 | 31 081.4 | 25 304.6 | 81.4 |
| 2004 | 29 736.2 | 24 406.4 | 82.1 |
| 2005 | 31 351.9 | 25 947.4 | 82.8 |
| 2006 | 30 081.8 | 24 708.7 | 82.1 |
| 2007 | 30 365.6 | 25 484.4 | 83.9 |
| 2008 | 28 454.0 | 23 798.2 | 83.6 |
| 2009 | 30 196.0 | 25 700.0 | 85.1 |
| 2010 | 29 733.0 | 24 904.4 | 83.8 |
| 2011 | 30 862.0 | 26 319.0 | 85.3 |
| 2012 | 30 786.0 | 25 551.8 | 83.0 |
| 2013 | 30 920.0 | 25 267.0 | 81.7 |
| 2014 | 31 230.0 | 27 864.2 | 89.2 |
| 2015 | 31 283.0 | 27 415.0 | 87.6 |
| 2016 | 33 763.5 | 28 480.5 | 84.4 |
| 2017 | 34 173.0 | 28 837.0 | 84.4 |
| 2018 | 34 532.6 | 28 231.7 | 81.8 |

***Waste Composition Data:*** The waste composition data were available for the years 1993, 2006 and 2014 until 2019 submission. To improve the quality of the inventory, an additional question on waste composition data has been added to the TurkStat's *Municipal Waste Statistics Survey* and, TurkStat's waste composition survey and results for the years 2016, 2017 and 2018 are used. For 1993, the source of the data is *TurkStat, Environmental Statistics, Household Solid Waste Composition and Tendency Survey Results, 1993*. The results of this survey on a national scale are also published in *OECD Environmental Data, Compendium 2006-2008*. The 2006 data was developed under the Solid Waste Master Plan Project of MoEF and published in *Waste Management Action Plan, 2008-2012; MoEF*. The source of the 2014 waste composition data is *National Waste Management and Action Plan, 2016-2023; MoEU*. The source of the 2016, 2017 and 2018 waste composition data is TurkStat's *Municipal Waste Statistics Survey* as mentioned above. This survey is conducted biennially, but the waste composition data is planned to compile annually by inquiring about the previous year data.

Waste composition data for the remaining years, were estimated by time series analysis methods in 2019 submission. For missing value imputation R programming language was used. Since, it is not possible to generate missing years before 1993 with interpolation. Thus, for providing time series consistency, time series analysis methods were tried and compared with simplicing techniques of IPCC guidelines. After the comprehensive study carried out for imputation of missing years, two time series analysis methods were found statistically better than others. These are Linear Weighted Moving Average (LWMA) and Exponential Weighted Moving Average (EWMA). An exponential moving average is calculated similarly to a linear weighted moving average, but uses an exponentially weighted multiplier. Both of them are calculated by adding the moving average of a certain share of the current value to the previous value. They assign more meaning to the recent values and less to the period's beginning.

LWMA: Weights decrease in arithmetical progression. The observations directly next to a central value i, have weight 1/2, the observations one further away (i-2,i+2) have weight 1/3, the next(i-3,i+3) have weight 1/4, ...

EWMA: uses weighting factors which decrease exponentially. The observations directly next to a central value i, have weight 1/2^1, the observations one further away (i-2,i+2) have weight 1/2^2, the next (i-3,i+3) have weight 1/2^3, ...

(The R Project for Statistical Computing- "Time Series Missing Value Imputation", Package 'imputeTS', Version: 2.7, June 20, 2018)

As a result, LWMA method was preferred because the values of both the first years and the last years were the same in the EWMA method.

In conclusion, based on the ERT findings in the latest review, Turkey re-examined the completeness and accuracy of different data sources and, updated the time series by disseminating the waste composition data along the years 1990-2018 in order to provide a consistent time series.

Table 7.10 contains these statistically estimated data with the official waste composition data.

**Table 7.10 Waste composition data**

(%)

| Year | Food | Garden | Paper | Textile | Plastics | Metal | Glass | Other |
|---|---|---|---|---|---|---|---|---|
| 1990 | 58.29 | 0.95 | 7.90 | 3.81 | 2.81 | 1.00 | 2.76 | 22.48 |
| 1991 | 59.26 | 0.79 | 7.58 | 3.84 | 2.84 | 1.00 | 2.63 | 22.05 |
| 1992 | 60.47 | 0.59 | 7.18 | 3.88 | 2.88 | 1.00 | 2.47 | 21.53 |
| 1993 (1) | 64.00 | 0.00 | 6.00 | 4.00 | 3.00 | 1.00 | 2.00 | 20.00 |
| 1994 | 60.00 | 0.67 | 7.33 | 3.87 | 2.87 | 1.00 | 2.53 | 21.73 |
| 1995 | 58.00 | 1.00 | 8.00 | 3.80 | 2.80 | 1.00 | 2.80 | 22.60 |
| 1996 | 56.00 | 1.33 | 8.67 | 3.73 | 2.73 | 1.00 | 3.07 | 23.47 |
| 1997 | 54.00 | 1.67 | 9.33 | 3.67 | 2.67 | 1.00 | 3.33 | 24.33 |
| 1998 | 52.00 | 2.00 | 10.00 | 3.60 | 2.60 | 1.00 | 3.60 | 25.20 |
| 1999 | 50.00 | 2.33 | 10.67 | 3.53 | 2.53 | 1.00 | 3.87 | 26.07 |
| 2000 | 48.00 | 2.67 | 11.33 | 3.47 | 2.47 | 1.00 | 4.13 | 26.93 |
| 2001 | 46.00 | 3.00 | 12.00 | 3.40 | 2.40 | 1.00 | 4.40 | 27.80 |
| 2002 | 44.00 | 3.33 | 12.67 | 3.33 | 2.33 | 1.00 | 4.67 | 28.67 |
| 2003 | 42.00 | 3.67 | 13.33 | 3.27 | 2.27 | 1.00 | 4.93 | 29.53 |
| 2004 | 37.15 | 5.39 | 14.31 | 2.98 | 2.83 | 1.08 | 5.44 | 30.82 |
| 2005 | 36.45 | 5.31 | 14.69 | 2.98 | 2.64 | 1.06 | 5.56 | 31.31 |
| 2006 (2) | 34.00 | 5.00 | 16.00 | 3.00 | 2.00 | 1.00 | 6.00 | 33.00 |
| 2007 | 36.94 | 5.37 | 14.42 | 2.98 | 2.77 | 1.07 | 5.48 | 30.97 |
| 2008 | 38.41 | 5.55 | 13.63 | 2.97 | 3.16 | 1.11 | 5.21 | 29.95 |
| 2009 | 39.88 | 5.74 | 12.84 | 2.96 | 3.54 | 1.15 | 4.95 | 28.94 |
| 2010 | 41.35 | 5.92 | 12.06 | 2.95 | 3.93 | 1.19 | 4.69 | 27.92 |
| 2011 | 46.34 | 5.98 | 11.44 | 2.10 | 6.23 | 1.52 | 4.51 | 21.88 |
| 2012 | 51.11 | 6.41 | 9.52 | 1.81 | 7.80 | 1.71 | 3.88 | 17.77 |
| 2013 | 50.84 | 6.45 | 9.36 | 1.93 | 7.58 | 1.67 | 3.82 | 18.33 |
| 2014 (3) | 48.70 | 6.84 | 8.11 | 2.90 | 5.86 | 1.37 | 3.38 | 22.84 |
| 2015 | 52.37 | 5.67 | 10.47 | 1.09 | 9.17 | 1.95 | 4.34 | 14.94 |
| 2016 (4) | 55.13 | 5.68 | 11.87 | 0.00 | 11.02 | 2.28 | 4.70 | 9.32 |
| 2017 (5) | 53.75 | 3.91 | 11.91 | 0.00 | 11.36 | 2.33 | 5.22 | 11.53 |
| 2018 (6) | 54.62 | 4.96 | 10.89 | 0.00 | 12.32 | 2.15 | 5.13 | 9.93 |

(1) TurkStat, Environmental Statistics, Household Solid Waste Composition and Tendency Survey Results, 1993

(2) MoEF, Waste Management Action Plan, 2008-2012

(3) MoEU, National Waste Management and Action Plan, 2016-2023

(4), (5), (6) TurkStat, Municipal Waste Statistics Survey Results, 2018

### Industrial Waste Activity Data

The annual data of industrial waste disposed in the municipal SWDS are collected by TurkStat's *Manufacturing Industry Establishments Water, Wastewater and Waste Statistics Survey* which is applied to manufacturing industry establishments having 50 or more employees. However, the survey could not be conducted on a regular basis before 2008, and since 2008 has started to be held biennially. The data are available for the years 1994-1997, 2000, 2004, 2008, 2010, 2012, 2014, 2016 and 2018. The missing data for the remaining years between 1994 and 2018 were estimated by linear interpolation.

Data are available from the statistical surveys described above (noting the need to resolving data gaps for intervening years when survey data were not available). Data on industrial waste generation were not available prior to 1994. Recognizing that, in accordance with the 2006 IPCC Guidelines, data on industrial waste generation are needed for at least the last 50 years, Turkey has made assumptions to collect the full time series of data. As described further below, between 1950 and 1993, the amount of waste generated is estimated based on the waste generation rate in 1994 and GDP data for each year.

The amount of degradable organic material from industrial waste disposed at SWDS is taken into account since only those industrial wastes which are expected to contain DOC and fossil carbon should be considered for the purpose of emission estimations from SWDS. Excluding the industrial waste that is already included in the Municipal Waste Statistics (to avoid double counting), Turkey concluded that there are no separately managed industrial waste disposal practices in the SWDS. For this reason, the distribution of industrial waste by waste management type is 100% unmanaged for the whole time series.

The amount of industrial waste disposed of in unmanaged SWDS consists of dumping onto land, burial and disposals to the Organized Industrial Zones.

Annual industrial waste at the SWDS and distribution of waste by waste management type are given in Table 7.11.

**Table 7.11 Annual IW and distribution of waste by management type, 1990-2018**

| | Annual IW at the SWDS (kt) | | | Distribution of waste (%) | |
|---|---|---|---|---|---|
| **Year** | **Total** | **Managed** | **Unmanaged** | **Managed** | **Unmanaged** |
| 1990 | 12.9 | NO | 12.9 | 0.0 | 100.0 |
| 1991 | 12.9 | NO | 12.9 | 0.0 | 100.0 |
| 1992 | 13.6 | NO | 13.6 | 0.0 | 100.0 |
| 1993 | 15.4 | NO | 15.4 | 0.0 | 100.0 |
| 1994 | 11.4 | NO | 11.4 | 0.0 | 100.0 |
| 1995 | 6.7 | NO | 6.7 | 0.0 | 100.0 |
| 1996 | 8.8 | NO | 8.8 | 0.0 | 100.0 |
| 1997 | 0.8 | NO | 0.8 | 0.0 | 100.0 |
| 1998 | 4.8 | NO | 4.8 | 0.0 | 100.0 |
| 1999 | 7.3 | NO | 7.3 | 0.0 | 100.0 |
| 2000 | 10.4 | NO | 10.4 | 0.0 | 100.0 |
| 2001 | 5.6 | NO | 5.6 | 0.0 | 100.0 |
| 2002 | 4.4 | NO | 4.4 | 0.0 | 100.0 |
| 2003 | 3.3 | NO | 3.3 | 0.0 | 100.0 |
| 2004 | 1.6 | NO | 1.6 | 0.0 | 100.0 |
| 2005 | 2.7 | NO | 2.7 | 0.0 | 100.0 |
| 2006 | 3.3 | NO | 3.3 | 0.0 | 100.0 |
| 2007 | 4.0 | NO | 4.0 | 0.0 | 100.0 |
| 2008 | 3.9 | NO | 3.9 | 0.0 | 100.0 |
| 2009 | 3.4 | NO | 3.4 | 0.0 | 100.0 |
| 2010 | 4.2 | NO | 4.2 | 0.0 | 100.0 |
| 2011 | 4.5 | NO | 4.5 | 0.0 | 100.0 |
| 2012 | 4.7 | NO | 4.7 | 0.0 | 100.0 |
| 2013 | 5.7 | NO | 5.7 | 0.0 | 100.0 |
| 2014 | 6.1 | NO | 6.1 | 0.0 | 100.0 |
| 2015 | 4.0 | NO | 4.0 | 0.0 | 100.0 |
| 2016 | 2.1 | NO | 2.1 | 0.0 | 100.0 |
| 2017 | 2.8 | NO | 2.8 | 0.0 | 100.0 |
| 2018 | 3.4 | NO | 3.4 | 0.0 | 100.0 |

***GDP Data:*** Historical data for GDP by production approach are obtained from TurkStat's *National Accounts* from 1923 onwards. Between the years 1998-2018, GDP data have been updated by using Annual GDP based on 2009. Compared to the previous submission, 2017 GDP data has been revised by the TurkStat. GDP data in current prices used for emission estimations are given in Table 7.12.

**Table 7.12 GDP by production approach, 1950-2018**

**(million USD)**

| Year | GDP | Year | GDP |
|---|---|---|---|
| 1950 | 3 469 | 1985 | 66 408 |
| 1951 | 4 167 | 1986 | 75 018 |
| 1952 | 4 793 | 1987 | 85 638 |
| 1953 | 5 585 | 1988 | 90 495 |
| 1954 | 5 700 | 1989 | 106 123 |
| 1955 | 6 854 | 1990 | 149 195 |
| 1956 | 7 909 | 1991 | 149 156 |
| 1957 | 10 518 | 1992 | 156 656 |
| 1958 | 12 552 | 1993 | 177 332 |
| 1959 | 15 687 | 1994 | 131 639 |
| 1960 | 9 932 | 1995 | 168 080 |
| 1961 | 5 512 | 1996 | 181 077 |
| 1962 | 6 402 | 1997 | 188 735 |
| 1963 | 7 402 | 1998 | 277 468 |
| 1964 | 7 872 | 1999 | 253 622 |
| 1965 | 8 419 | 2000 | 271 768 |
| 1966 | 9 997 | 2001 | 200 998 |
| 1967 | 11 144 | 2002 | 236 338 |
| 1968 | 18 008 | 2003 | 313 776 |
| 1969 | 20 128 | 2004 | 402 952 |
| 1970 | 18 825 | 2005 | 499 874 |
| 1971 | 16 847 | 2006 | 547 832 |
| 1972 | 21 319 | 2007 | 677 438 |
| 1973 | 26 854 | 2008 | 776 643 |
| 1974 | 36 985 | 2009 | 646 893 |
| 1975 | 46 300 | 2010 | 772 365 |
| 1976 | 52 996 | 2011 | 831 696 |
| 1977 | 60 613 | 2012 | 871 125 |
| 1978 | 66 277 | 2013 | 950 355 |
| 1979 | 80 960 | 2014 | 934 857 |
| 1980 | 67 457 | 2015 | 861 879 |
| 1981 | 70 419 | 2016 | 862 746 |
| 1982 | 63 485 | 2017 | 852 618 |
| 1983 | 60 373 | 2018 | 789 043 |
| 1984 | 58 643 | | |

Source: TurkStat, National Accounts

***Waste Generation Rate:*** To calculate waste generation rate (kt/million USD GDP/yr), between 1950 and 1994, the amount of industrial waste (IW) generated and GDP data are used. As noted above, the amount of IW generated for the surveyed years (1994-1997, 2000, 2004, 2008, 2010, 2012, 2014, 2016 and 2018) are obtained from TurkStat's *Manufacturing Industry Establishments Water, Wastewater and Waste Statistics Survey.* Missing data for the years not surveyed (1998, 1999, 2001-2003, 2005-2007, 2009, 2011, 2013 and 2015) are estimated by linear interpolation. 2017 waste generation rate of previous submission is recalculated by interpolation method due to the availability of 2018 IW data. Due

to lack of historical IW generated data, the waste generation rate of 1994 (0.09 kt/million USD GDP/yr) is used for 1950-1993 (see Table 7.13).

***% to SWDS:*** To calculate the percentage of industrial waste generated which goes to SWDS, the amount of industrial waste generated and industrial waste landfilled data are used. The amount of industrial waste landfilled for the surveyed years (1994-1997, 2000, 2004, 2008, 2010, 2012, 2014, 2016 and 2018) are obtained from TurkStat's *Manufacturing Industry Establishments Water, Wastewater and Waste Statistics Survey.* 2017 % to SWDS data of previous submission is recalculated by interpolation method due to the availability of 2018 IW generated data. Due to lack of industrial waste generated data, the percentage of industrial waste sent to SWDS in 1994 (0.1%) is used for 1950-1993.

The percentage of industrial waste to SWDS is obtained by dividing the amount of industrial waste landfilled by industrial waste generated data.

Industrial waste AD are given in detail in Table 7.13.

**Table 7.13 Industrial waste activity data, 1990-2018**

| Year | GDP (million USD) | Waste generation rate (kt/million USD/yr) | Total IW (kt) | % to SWDS (%) | Total to SWDS (kt) |
|---|---|---|---|---|---|
| 1990 | 149 195.0 | 0.09 | 13 615.4 | 0.10 | 12.9 |
| 1991 | 149 156.0 | 0.09 | 13 611.8 | 0.10 | 12.9 |
| 1992 | 156 656.0 | 0.09 | 14 296.3 | 0.10 | 13.6 |
| 1993 | 177 332.0 | 0.09 | 16 183.1 | 0.10 | 15.4 |
| 1994 | 131 639.0 | 0.09 | 12 013.2 | 0.10 | 11.4 |
| 1995 | 168 080.0 | 0.07 | 12 492.8 | 0.05 | 6.7 |
| 1996 | 181 077.0 | 0.08 | 13 921.1 | 0.06 | 8.8 |
| 1997 | 188 735.0 | 0.08 | 14 659.5 | 0.01 | 0.8 |
| 1998 | 277 468.4 | 0.07 | 20 173.4 | 0.02 | 4.8 |
| 1999 | 253 622.3 | 0.07 | 17 179.8 | 0.04 | 7.3 |
| 2000 | 271 767.8 | 0.06 | 17 058.9 | 0.06 | 10.4 |
| 2001 | 200 997.6 | 0.06 | 11 644.5 | 0.05 | 5.6 |
| 2002 | 236 337.8 | 0.05 | 12 548.8 | 0.03 | 4.4 |
| 2003 | 313 776.3 | 0.05 | 15 142.8 | 0.02 | 3.3 |
| 2004 | 402 951.6 | 0.04 | 17 497.5 | 0.01 | 1.6 |
| 2005 | 499 874.0 | 0.04 | 18 288.0 | 0.01 | 2.7 |
| 2006 | 547 832.4 | 0.03 | 16 296.5 | 0.02 | 3.3 |
| 2007 | 677 438.2 | 0.02 | 15 519.6 | 0.03 | 4.0 |
| 2008 | 776 643.4 | 0.02 | 12 481.6 | 0.03 | 3.9 |
| 2009 | 646 892.7 | 0.02 | 10 795.7 | 0.03 | 3.4 |
| 2010 | 772 365.0 | 0.02 | 13 366.5 | 0.03 | 4.2 |
| 2011 | 831 695.6 | 0.02 | 14 080.4 | 0.03 | 4.5 |
| 2012 | 871 125.0 | 0.02 | 14 420.3 | 0.03 | 4.7 |
| 2013 | 950 355.3 | 0.02 | 15 863.1 | 0.04 | 5.7 |
| 2014 | 934 856.8 | 0.02 | 15 733.5 | 0.04 | 6.1 |
| 2015 | 861 879.3 | 0.02 | 15 377.8 | 0.03 | 4.0 |
| 2016 | 862 745.6 | 0.02 | 16 266.7 | 0.01 | 2.1 |
| 2017 | 852 618.0 | 0.02 | 20 400.3 | 0.01 | 2.8 |
| 2018 | 789 042.8 | 0.03 | 22 881.1 | 0.01 | 3.4 |

**Methane Correction Factor (MCF)**

Due to the assumption that all managed SWDS are categorized under anaerobic managed SWDS, the default MCF from the 2006 IPCC Guidelines for anaerobic managed SWDS (1.0) is taken for managed SWDS. Since there is no information about classification of deep (>=5 meters waste and/or high water table) or shallow (<5 meters waste) for unmanaged waste disposal sites, Turkey has used the average of the default MCFs for unmanaged-deep (0.8) and unmanaged-shallow (0.4) in the absence of country-specific information for unmanaged waste disposal practices (0.6).

A weighted average of MCF from the estimated distribution of site types is needed for the calculation $CH_4$ emissions from solid waste disposal sites. Calculated values for the MCF are given in Table 7.14.

**Table 7.14 Weighted averages of MCF, 1990-2018**

**(weighted average fraction)**

| Year | MCF for MSW | MCF for IW | MCF for SS | MCF for CW |
|---|---|---|---|---|
| 1990 | 0.60 | 0.60 | 0.60 | 0.00 |
| 1991 | 0.60 | 0.60 | 0.60 | 0.00 |
| 1992 | 0.62 | 0.60 | 0.60 | 0.00 |
| 1993 | 0.62 | 0.60 | 0.60 | 0.00 |
| 1994 | 0.62 | 0.60 | 0.60 | 0.00 |
| 1995 | 0.63 | 0.60 | 0.60 | 0.00 |
| 1996 | 0.65 | 0.60 | 0.60 | 0.00 |
| 1997 | 0.68 | 0.60 | 0.60 | 0.00 |
| 1998 | 0.69 | 0.60 | 0.74 | 0.00 |
| 1999 | 0.71 | 0.60 | 0.81 | 0.00 |
| 2000 | 0.72 | 0.60 | 0.82 | 0.00 |
| 2001 | 0.74 | 0.60 | 0.83 | 0.00 |
| 2002 | 0.71 | 0.60 | 0.77 | 0.00 |
| 2003 | 0.72 | 0.60 | 0.79 | 0.71 |
| 2004 | 0.71 | 0.60 | 0.85 | 0.72 |
| 2005 | 0.71 | 0.60 | 0.79 | 0.78 |
| 2006 | 0.75 | 0.60 | 0.75 | 0.82 |
| 2007 | 0.76 | 0.60 | 0.76 | 0.85 |
| 2008 | 0.78 | 0.60 | 0.77 | 0.88 |
| 2009 | 0.79 | 0.60 | 0.75 | 0.89 |
| 2010 | 0.82 | 0.60 | 0.74 | 0.88 |
| 2011 | 0.82 | 0.60 | 0.74 | 0.90 |
| 2012 | 0.84 | 0.60 | 0.75 | 0.92 |
| 2013 | 0.86 | 0.60 | 0.75 | 0.91 |
| 2014 | 0.86 | 0.60 | 0.76 | 0.90 |
| 2015 | 0.87 | 0.60 | 0.77 | 0.91 |
| 2016 | 0.87 | 0.60 | 0.77 | 0.92 |
| 2017 | 0.88 | 0.60 | 0.79 | 0.89 |
| 2018 | 0.91 | 0.60 | 0.81 | 0.88 |

### Choice of Emission Factor and Other Parameters

2006 IPCC default values are selected for utilization in the IPCC Waste Model using the FOD method with the starting year 1950.

***Degradable Organic Carbon (DOC):*** Degradable organic carbon (DOC) is the organic carbon in waste that is accessible to biochemical decomposition. IPCC default values for the DOC content of main components (waste types/material) used in the model are listed in Table 7.15. For sewage sludge 0.05 is taken and for clinical waste 0.15 is used according to *Table 2.6 in the 2006 IPCC, Volume 5, Chapter 2.*

**Table 7.15 DOC values by individual waste type**

**(weight fraction, wet basis)**

| Waste Type | Food waste | Garden | Paper | Textiles |
|---|---|---|---|---|
| **DOC** | 0.15 | 0.20 | 0.40 | 0.24 |

DOC by weight is calculated from the degradable portion of the MSW based on *Equation 3.7 in the 2006 IPCC, Volume 5, Chapter 3* and the IPCC defaults are taken from *Table 2.4 in the 2006 IPCC, Volume 5, Chapter2*.

$$\%\,DOC\ (by\ net\ weight)\ =\ (0.15\ x\ A)\ +\ (0.20\ x\ B)\ +\ (0.40\ x\ C)\ +\ (0.24\ x\ D)$$

Where:

A = fraction of food waste in MSW

B = fraction of garden waste in MSW

C = fraction of paper in MSW

D = fraction of textiles in MSW

The calculated values of DOC by weight for the inventory years of 1990-2017 are listed below in Table 7.16.

**Table 7.16 DOC by weight, 1990-2018**

| Year | %DOC | Year | %DOC |
|---|---|---|---|
| 1990 | 13.01 | 2005 | 13.12 |
| 1991 | 13.00 | 2006 | 13.22 |
| 1992 | 12.99 | 2007 | 13.10 |
| 1993 | 12.96 | 2008 | 13.04 |
| 1994 | 12.99 | 2009 | 12.98 |
| 1995 | 13.01 | 2010 | 12.92 |
| 1996 | 13.03 | 2011 | 13.23 |
| 1997 | 13.05 | 2012 | 13.19 |
| 1998 | 13.06 | 2013 | 13.13 |
| 1999 | 13.08 | 2014 | 12.61 |
| 2000 | 13.10 | 2015 | 13.44 |
| 2001 | 13.12 | 2016 | 14.15 |
| 2002 | 13.13 | 2017 | 13.61 |
| 2003 | 13.15 | 2018 | 13.54 |
| 2004 | 13.09 | | |

***Fraction of Degradable Organic Carbon Which Decomposes ($DOC_f$):*** In the absence of country-specific information, the recommended IPCC default value for $DOC_f$ (0.5) is used for the entire time series.

***Methane Generation Rate Constant (k):*** IPCC default methane generation rate constants are selected according to the IPCC climate zone definitions in the model. Default k values for dry temperate are listed below and applied for the entire time series.

**Table 7.17 Dry temperate k values by waste type**

**(years$^{-1}$)**

| Waste Type | Food waste | Garden | Paper | Textiles |
|---|---|---|---|---|
| **k** | 0.06 | 0.05 | 0.04 | 0.04 |

***Fraction of Methane in Generated Landfill Gas (F):*** Most waste in SWDS generates a gas with approximately 50% $CH_4$. The IPCC default value for the fraction of $CH_4$ in landfill gas (0.5) is used for the entire time series.

***Oxidation Factor (OX):*** The oxidation factor reflects the amount of $CH_4$ from SWDS that is oxidized in the soil or other material covering the waste. The IPCC default value for OX is zero for managed, unmanaged and uncategorized SWDS and this is the value applied by Turkey for the entire time series.

**Methane Recovery**

The recovery of methane and its subsequent utilization is also considered in the inventory. Methane recovery from landfill gas started to be implemented in Turkey in 2002. Therefore, the quantity of recovered methane is subtracted from the methane produced beginning in the year 2002. In 2013, *Waste Disposal and Recovery Facilities Survey, 2012* was applied to all waste disposal and recovery facilities having a license or a temporary license, and regardless of license, to controlled landfill sites, incineration plants and composting plants operated by or on behalf of municipalities. Based on the information obtained from the survey, TurkStat sends official letters to each facility recovering methane for requesting the quantity of methane gas and electricity production for the entire operating period of the facility every year. The facilities estimate the quantity of methane recovered by measuring of gas recovered. The obtained information on the quantity of produced electricity is used for cross-check of the quantity of methane recovered.

The coverage of the facilities is followed and updated depending on availability of new information; including information obtained from the facility, the information from the latest (biennial) survey *(Waste Disposal and Recovery Facilities Survey, 2016)* etc. The emissions from energy production from the recovered $CH_4$ gas in SWDS were included in the category of Public Electricity and Heat Production (1.A.1.a).

The number of managed and unmanaged SWDS with landfill gas recovery and the amount of recovered methane, by year, are given in Table 7.18.

**Table 7.18 Methane recovery, 1990-2018**

| Year | Number of managed SWDS with landfill gas recovery | Number of unmanaged SWDS with landfill gas recovery | Recovered methane in managed SWDS (kt) | Recovered methane in unmanaged SWDS (kt) |
|---|---|---|---|---|
| 1990-2001 | NA | NA | NO | NO |
| 2002 | 1 | NA | 1.5 | NO |
| 2003 | 1 | NA | 2.5 | NO |
| 2004 | 1 | NA | 2.3 | NO |
| 2005 | 1 | NA | 1.7 | NO |
| 2006 | 1 | NA | 2.2 | NO |
| 2007 | 2 | NA | 8.3 | NO |
| 2008 | 3 | NA | 21.4 | NO |
| 2009 | 4 | NA | 36.5 | NO |
| 2010 | 5 | NA | 47.9 | NO |
| 2011 | 8 | NA | 56.7 | NO |
| 2012 | 13 | NA | 96.2 | NO |
| 2013 | 15 | 1 | 150.9 | 8.8 |
| 2014 | 18 | 1 | 171.8 | 8.0 |
| 2015 | 24 | 1 | 176.6 | 8.0 |
| 2016 | 34 | 1 | 231.5 | 6.0 |
| 2017 | 37 | 1 | 305.6 | 15.8 |
| 2018 | 52 | 1 | 340.0 | 13.0 |

An additional question about landfill gas flaring has been added to the *Waste Disposal and Recovery Facilities Survey, 2014* and been also asked via *Waste Disposal and Recovery Facilities Survey, 2018*. There is still no official data on landfill gas flaring in response to the *Waste Disposal and Recovery Facilities Survey, 2018*. It will be also considered in the upcoming inventory in the case that new information is obtained.

**Sewage Sludge**

In this submission sewage sludge is estimated by TurkStat with official data. This sludge is domestic wastewater treatment sludge from municipal wastewater treatment plants. Data on sludge quantity are compiled on wet basis and converted to dry matter by using the coefficients included in the guidelines of the European Union Statistical Office (EUROSTAT). And for the emissions calculations dry basis is used. The source of sewage sludge is TurkStat's *Municipal Wastewater Statistics Survey.* In this survey, disposal methods named 'Dumping on to land', 'Municipal dumping sites', 'Controlled landfill sites', 'Buried' and 'Other' are added together and assumed as the total sludge that stored in SWDS and each sludge amount can be seen from Table 7.37 in Wastewater Treatment and Discharge part (Category 5.D)

Methane emissions from sewage sludge are listed below in Table 7.19.

**Table 7.19 $CH_4$ generated from SS at SWDS, 1990-2018**

(kt)

| Year | Total | Managed | Unmanaged |
|---|---|---|---|
| 1990 | NO | NO | NO |
| 1991 | 0.001 | NO | 0.001 |
| 1992 | 0.002 | NO | 0.002 |
| 1993 | 0.003 | NO | 0.003 |
| 1994 | 0.003 | NO | 0.003 |
| 1995 | 0.004 | NO | 0.004 |
| 1996 | 0.005 | NO | 0.005 |
| 1997 | 0.006 | 0.000 | 0.006 |
| 1998 | 0.007 | 0.000 | 0.007 |
| 1999 | 0.021 | 0.006 | 0.014 |
| 2000 | 0.055 | 0.029 | 0.026 |
| 2001 | 0.098 | 0.058 | 0.040 |
| 2002 | 0.149 | 0.094 | 0.055 |
| 2003 | 0.240 | 0.143 | 0.097 |
| 2004 | 0.317 | 0.190 | 0.127 |
| 2005 | 0.419 | 0.269 | 0.151 |
| 2006 | 0.537 | 0.339 | 0.198 |
| 2007 | 0.669 | 0.403 | 0.266 |
| 2008 | 0.806 | 0.472 | 0.334 |
| 2009 | 0.947 | 0.546 | 0.401 |
| 2010 | 1.087 | 0.613 | 0.474 |
| 2011 | 1.227 | 0.673 | 0.554 |
| 2012 | 1.358 | 0.731 | 0.627 |
| 2013 | 1.479 | 0.787 | 0.693 |
| 2014 | 1.576 | 0.834 | 0.742 |
| 2015 | 1.650 | 0.875 | 0.776 |
| 2016 | 1.711 | 0.908 | 0.802 |
| 2017 | 1.757 | 0.936 | 0.821 |
| 2018 | 1.793 | 0.963 | 0.830 |

**Table 7.20 Annual SS and distribution of waste by management type, 1990-2018**

| | Annual SS at the SWDS (kt) | | | Distribution of waste (%) | |
|---|---|---|---|---|---|
| Year | Total | Managed | Unmanaged | Managed | Unmanaged |
| 1990-94 | 1.5 | NO | 1.5 | 0.0 | 100.0 |
| 1995 | 2.4 | NO | 2.4 | 0.0 | 100.0 |
| 1996 | 2.0 | 0.0 | 2.0 | 1.0 | 99.0 |
| 1997 | 3.0 | 0.0 | 3.0 | 0.8 | 99.2 |
| 1998 | 19.6 | 6.6 | 12.9 | 33.9 | 66.1 |
| 1999 | 45.2 | 23.5 | 21.6 | 52.1 | 47.9 |
| 2000 | 58.0 | 32.0 | 26.0 | 55.1 | 44.9 |
| 2001 | 70.8 | 40.4 | 30.4 | 57.1 | 42.9 |
| 2002 | 133.2 | 55.8 | 77.4 | 41.9 | 58.1 |
| 2003 | 118.4 | 57.5 | 60.9 | 48.6 | 51.4 |
| 2004 | 145.5 | 92.1 | 53.4 | 63.3 | 36.7 |
| 2005 | 184.6 | 88.8 | 95.7 | 48.1 | 51.9 |
| 2006 | 223.7 | 85.6 | 138.1 | 38.3 | 61.7 |
| 2007 | 238.1 | 95.2 | 142.9 | 40.0 | 60.0 |
| 2008 | 252.6 | 104.8 | 147.7 | 41.5 | 58.5 |
| 2009 | 268.0 | 101.8 | 166.1 | 38.0 | 62.0 |
| 2010 | 283.3 | 98.8 | 184.5 | 34.9 | 65.1 |
| 2011 | 280.2 | 100.0 | 180.2 | 35.7 | 64.3 |
| 2012 | 277.0 | 101.1 | 175.9 | 36.5 | 63.5 |
| 2013 | 250.5 | 96.3 | 154.1 | 38.5 | 61.5 |
| 2014 | 223.9 | 91.5 | 132.4 | 40.9 | 59.1 |
| 2015 | 210.0 | 87.3 | 122.7 | 41.6 | 58.4 |
| 2016 | 196.1 | 83.0 | 113.1 | 42.3 | 57.7 |
| 2017 | 180.7 | 84.2 | 96.5 | 46.6 | 53.4 |
| 2018 | 165.2 | 85.4 | 79.8 | 51.7 | 48.3 |

Compared to previous submission, 2017 sewage sludge data has been recalculated by linear interpolation in 2020 inventory submission due to the availability of 2018 survey data.

**Clinical Waste**

Data have been collected according to the manual for the implementation of regulation (EC) no 2150/2002 on waste statistics and to the framework of the OECD/EUROSTAT core set of environmental data and indicators. For the reference year 2016 and before, data was produced based on the results of the survey conducted by Turkish Statistical Institute which was applied to the health institutions listed in Medical Waste Control Regulation as producers of large quantities of waste (university hospitals and their clinics, general purpose hospitals and their clinics, maternity hospitals and their clinics and military hospitals and their clinics) as Waste Statistics of Health Institutions.

Since 2017, Medical Waste Statistics have been prepared and published annually using medical waste data from the health institutions (universities, maternity and general purpose hospitals and clinics) included in the administrative records of the Ministry of Environment and Urbanization.

Also, "Zero Waste" project is expected to come into force. The Zero Waste Project is aimed at managing waste and leaving future generations a clean and developed Turkey. Carried out by the Ministry of

Environment and Urbanization, the project will initially be implemented in public bodies. With this project, the collection and processing of all wastes including medical wastes might change. Hence a recalculation is likely to be inevitable.

Methane emissions caused by clinical waste are quite small as seen in Table 7.21.

**Table 7.21 $CH_4$ generated from CW at SWDS, 1990-2018**

(kt)

| Year | Total | Managed | Unmanaged |
|---|---|---|---|
| 1990-2003 | IE | IE | IE |
| 2004 | 0.1 | 0.0 | 0.1 |
| 2005 | 0.2 | 0.1 | 0.1 |
| 2006 | 0.3 | 0.1 | 0.1 |
| 2007 | 0.3 | 0.2 | 0.2 |
| 2008 | 0.4 | 0.2 | 0.2 |
| 2009 | 0.5 | 0.3 | 0.2 |
| 2010 | 0.6 | 0.4 | 0.2 |
| 2011 | 0.7 | 0.5 | 0.2 |
| 2012 | 0.8 | 0.6 | 0.2 |
| 2013 | 0.9 | 0.7 | 0.2 |
| 2014 | 1.0 | 0.8 | 0.2 |
| 2015 | 1.1 | 0.8 | 0.3 |
| 2016 | 1.2 | 0.9 | 0.3 |
| 2017 | 1.3 | 1.0 | 0.3 |
| 2018 | 1.4 | 1.1 | 0.3 |

As can be seen from Table 7.22, values before 2003 were entered as "IE". The reason why those years were entered as "Included Elsewhere" is the clinical waste data were gathered by TurkStat in those years included in SWDS statistics via Municipal Waste Statistics Survey prior to 2003 because clinical waste was not collected separately before 2003. After 2003, clinical waste was collected separately by municipalities.

**Table 7.22 Annual CW and distribution of waste by management type, 1990-2018**

| | Annual CW at the SWDS (kt) | | | Distribution of waste (%) | |
|---|---|---|---|---|---|
| **Year** | **Total** | **Managed** | **Unmanaged** | **Managed** | **Unmanaged** |
| 1990-2002 | IE | IE | IE | NA | NA |
| 2003 | 48.9 | 14.0 | 34.9 | 28.7 | 71.3 |
| 2004 | 52.6 | 15.7 | 36.8 | 29.9 | 70.1 |
| 2005 | 47.7 | 21.1 | 26.6 | 44.3 | 55.7 |
| 2006 | 48.0 | 26.5 | 21.4 | 55.3 | 44.7 |
| 2007 | 51.2 | 32.3 | 18.8 | 63.2 | 36.8 |
| 2008 | 49.9 | 35.2 | 14.7 | 70.5 | 29.5 |
| 2009 | 57.1 | 41.6 | 15.5 | 72.9 | 27.1 |
| 2010 | 54.4 | 38.1 | 16.3 | 70.1 | 29.9 |
| 2011 | 58.8 | 44.6 | 14.2 | 75.8 | 24.2 |
| 2012 | 63.2 | 51.0 | 12.2 | 80.7 | 19.3 |
| 2013 | 65.1 | 50.8 | 14.3 | 78.1 | 21.9 |
| 2014 | 67.0 | 50.7 | 16.3 | 75.6 | 24.4 |
| 2015 | 67.7 | 52.5 | 15.2 | 77.6 | 22.4 |
| 2016 | 68.5 | 54.4 | 14.0 | 79.5 | 20.5 |
| 2017 | 78.4 | 56.3 | 22.0 | 71.9 | 28.1 |
| 2018 | 82.6 | 58.2 | 24.3 | 70.5 | 29.5 |

Compared to previous submission, 2017 clinical waste data has been revised by the TurkStat due to the corrections in methodology of incineration regulations (with the knowledge of only pathological clinical waste are incinerated, the amount of clinical waste disposed in incineration plants decreased, therefore the amount of clinical waste sterilized and disposed in SWDS increased for 2017).

### Uncertainties and Time-Series Consistency:

Uncertainty values for AD are estimated as 10.0% and 30.0% for managed and unmanaged SWDS, respectively. The uncertainty values reflect the uncertainty associated with some of the assumptions made by Turkey in estimating underlying activity data for municipal solid waste, industrial waste, sewage sludge and clinical waste. Although waste statistics on the amount of MSW generated are not available for all years after 1990, the periodic availability of survey data reduces the uncertainty of these data. The assumption that waste generation per capita prior to 1994 is constant likely overestimates the MSW generation for this time period. Further, estimating MSW generation based on population does not account for the fact that not all of the population may be serviced with waste collection. Combined uncertainty values of EFs are estimated as 30.8% and 38.1% for managed and unmanaged SWDS based on *Table 3.5 in 2006 IPCC, Volume 5, Chapter3.*

In 2019 submission Monte Carlo simulation is applied to waste sector entirely. The uncertainty estimate was performed by integrating the Monte Carlo simulation straight to the FOD model. According to Approach 2 (Monte Carlo method) results, the combined uncertainty range for $CH_4$ emissions from managed SWDS is -34.93% to +34.82% while for unmanaged SWDS is -46.85% to +47.31% in 2017. Detailed information is in Annex 2.

The estimates are calculated in a consistent manner over time series.

### Source-Specific QA/QC and Verification:

QA/QC procedures are implemented for each category in order to verify and improve the inventory under Turkey's QA/QC plan.

The data used in Solid Waste Disposal (CRF Category 5.A) are derived from waste statistics database of TurkStat. TurkStat is producing all its statistics according to the European Code of Practice Principles. Therefore, high quality data are used in the emission estimates of this category.

Moreover, QA work was conducted by an external reviewer (expert from CITEPA - Technical Reference Center for Air Pollution and Climate Change - in France) for this category in December 2019.

### Recalculation:

2017 data of MSW disposed in managed SWDS has been recalculated by linear interpolation in the 2020 inventory submission due to the availability of 2018 survey data. The amount of MSW disposed in unmanaged SWDS for 2017 was also impacted by this recalculation. 2017 waste generation rate of previous submission is recalculated by interpolation method due to the availability of 2018 IW data. Another reason for the recalculation is update of the GDP data for 2017. 2017 % to SWDS data of previous submission is also recalculated by interpolation method due to the availability of 2018 IW generated data.

Methane recovery data from some landfill gas recovery facilities are updated after the year 2016 as a result of verification activities.

In summary, total $CH_4$ emissions from solid waste disposal sites have been recalculated for the years 2016 and 2017. Compared to the previous inventory submission, $CH_4$ emissions from Solid Waste Disposal in 2017 decreased by 0.39 percent (35.8 kt $CO_2$ eq.) and 0.34 percent (35.7 kt $CO_2$ eq.) in 2016. There is no recalculation for 1990. Also, methane recovery for energy purposes increased by 1.43 kt (0.4%) in 2017 and 1.43 kt (0.6%) in 2016.

### Planned Improvement:

As noted above, Turkey has asked a question on flaring of landfill gas to its *Waste Disposal and Recovery Facilities Survey, 2018*. According to the survey results, it has been determined that there is no flaring on waste disposal sites in Turkey. The results of the next survey *(Waste Disposal and Recovery Facilities Survey, 2020)* will be assessed, and if appropriate, the results incorporated into the next inventory submission(s).

## 7.3. Biological Treatment of Solid Waste (Category 5.B)

### Source Category Description:

This category includes emissions from composting and anaerobic digestion of organic waste. Turkey reports $CH_4$ and $N_2O$ emissions from composting of municipal solid waste (5.B.1). Turkey has no information available on the existence of anaerobic digestion of organic waste. Therefore, consistent with the 2006 IPCC Guidelines, Turkey assumes that there is no anaerobic digestion in the country. However, this treatment process will be also considered and reported in coming years depending on availability of any information.

The total biological treatment of solid waste emissions for both gases increased by 27.3% (4.4 kt $CO_2$ eq.) between 1990 (16.1 kt $CO_2$ eq.) and 2018 (20.5 kt $CO_2$ eq.).

### Methodological Issues:

To estimate both $CH_4$ and $N_2O$ emissions for composting, Turkey multiples the mass of organic waste composted by a default emission factor (the IPCC T1 method), as recommended in the 2006 IPCC Guidelines for National GHG Inventories. The $CH_4$ and $N_2O$ emissions of biological treatment can be estimated using the default method based on *Equations 4.1 and 4.2 in 2006 IPCC, Volume 5, Chapter 4* as given below.

$$CH_4\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

Where:

$CH_4$ Emissions = total $CH_4$ emissions in inventory year, Gg $CH_4$

$M_i$ = mass of organic waste treated by biological treatment type i, Gg

EF = emission factor for treatment i, g $CH_4$/kg waste treated

i = composting or anaerobic digestion

R = total amount of $CH_4$ recovered in inventory year, Gg $CH_4$

$$N_2O\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3}$$

Where:

$N_2O$ Emissions = total $N_2O$ emissions in inventory year, Gg $N_2O$

$M_i$ = mass of organic waste treated by biological treatment type i, Gg

EF = emission factor for treatment i, g $N_2O$/kg waste treated

i = composting or anaerobic digestion

**Collection of Activity Data**

The amount of municipal solid waste delivered to composting plants (1994-1998, 2001-2004, 2006, 2008, 2010, 2012, 2014, 2016 and 2018) are available in TurkStat's *Municipal Waste Statistics* as provided in Table 7.5. Remaining years are estimated with linear interpolation method except 1990-1993 period. For this beginning period, data was considered the same as for 1994. However, this data is the "amount of waste delivered to composting plants" not the "amount of waste treated by composting plants". Using this data directly will cause overestimation problem. On the other hand, the composted waste data are available in TurkStat's *Municipal Waste Statistics* for the years 2006, 2008 and 2010, and in TurkStat's *Waste Disposal and Recovery Facilities Statistics* for the years 2005, 2012, 2014, 2016 and 2018. For aforementioned years, composted waste amounts are taken into account instead of delivered amounts. The 2005 survey data is the oldest reliable data since it is asked to both municipalities and composting plants. Thus, for 2005, The 'fraction of waste composted' is calculated as the "amount of waste treated by composting plants" divided by the "amount of waste delivered to composting plants" in order to understand the "amount of waste treated by composting plants" is how much smaller than "amount of waste delivered to composting plants" to estimate the earlier years before 2001. Because after 2001, TurkStat has the composted waste data of the composting plant with the largest share (92.3% in 2017 and much bigger before 2017 due to the number of composting plants were less before 2017). The "amount of waste treated by composting plants" is approximately the half of the "amount of waste delivered to composting plants" in 2005 (0.49). This 'fraction of waste composted' is used as a multiplier for 1990-2001 period with the "amount of waste delivered to composting plants" survey data.

Since 2001, data of the composting plant with the largest share is located in Istanbul, which is the largest city in terms of population of Turkey, has been gathered with sending official letters directly to the firm itself. These data of the biggest composting plant are not used directly because at that time it would have caused underestimation problem. Those are just used as Surrogate Data (as one of the mentioned splicing techniques in 2006 IPCC Guidelines) with the survey data mentioned above, to avoid overestimation problem resulting from using the "amount of waste delivered to composting plants"

survey data for generating a complete time series. With this Surrogate Data, years in 2001-2018 period are generated. Besides, as of 2015, the official data on the amount of waste treated by composting plants were started to be compiled directly from the relevant facilities for years without survey. Therefore, 2015 and 2017 are real data taken directly from the sources and used instead of Surrogate Data estimations.

Number of composting plants and total composting capacity of each year in Turkey is listed below.

**Table 7.23 Number and total capacity of composting plants, 1994-2018**

| | 1994-1998 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|
| **# of composting plants with installed capacity** | 2 | 3 | 4 | 5 | 5 | 4 | 4 |
| **# of operating composting plants** | NA | NA | NA | NA | NA | NA | NA |
| **Capacity (thousand tonnes/year)** | 245 | 299 | 664 | 667 | 667 | 606 | 605 |

| | 2008 | 2010 | 2012 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| **# of composting plants with installed capacity** | 4 | 5 | 6 | 4 | 4 | 7 | 7 | 8 |
| **# of operating composting plants** | NA | NA | 6 | 3 | 3(3) | 5 | 5(3) | 6 |
| **Capacity (thousand tonnes/year)** | 551 | 556 | 389 | 310 | 310 | 424 | 424 | 483 |

Source: (1) TurkStat, Municipal Waste Statistics, 1994-2010
(2) TurkStat, Waste Disposal and Recovery Facilities Statistics, 2012-2018
(3) Official Letters

In response to the latest review in 2019, the number of composting plants with installed capacity and the operating ones are provided separately for available years in Table 7.23. Since the official data (number of facilities) of the survey indicates the number of composting plants with installed capacity, not those active ones in the relevant press releases, precise information on the number of facilities operating by year is not available before 2012. For years without survey (2015 and 2017), the number and total capacity of composting plants with installed capacity are assumed to be the same as the previous year.

**Choice of Emission Factor**

EFs of 4.0 g $CH_4$/kg waste treated (on a wet weight basis) and 0.24 g $N_2O$/kg waste treated (on a wet weight basis) are selected for the estimates of $CH_4$ and $N_2O$ emissions respectively, based on *Table 4.1 in the 2006 IPCC Guidelines, Volume 5, Chapter 4.*

The total annual amount of waste treated (as wet weight) by composting plants and emissions from composting are provided in Table 7.24.

**Table 7.24 Activity data, $CH_4$ and $N_2O$ emissions from composting, 1990-2018**

(kt)

| Year | Amount of waste treated by composting plants | $CH_4$ Emissions | $N_2O$ Emissions |
|---|---|---|---|
| 1990-94 | 93.7 | 0.37 | 0.022 |
| 1995 | 77.5 | 0.31 | 0.019 |
| 1996 | 87.2 | 0.35 | 0.021 |
| 1997 | 87.9 | 0.35 | 0.021 |
| 1998 | 81.1 | 0.32 | 0.019 |
| 1999 | 89.5 | 0.36 | 0.021 |
| 2000 | 97.9 | 0.39 | 0.023 |
| 2001 | 122.6 | 0.49 | 0.029 |
| 2002 | 186.2 | 0.74 | 0.045 |
| 2003 | 221.2 | 0.88 | 0.053 |
| 2004 | 182.4 | 0.73 | 0.044 |
| 2005 | 165.4 | 0.66 | 0.040 |
| 2006 | 153.4 | 0.61 | 0.037 |
| 2007 | 176.7 | 0.71 | 0.042 |
| 2008 | 153.8 | 0.62 | 0.037 |
| 2009 | 137.8 | 0.55 | 0.033 |
| 2010 | 174.6 | 0.70 | 0.042 |
| 2011 | 169.6 | 0.68 | 0.041 |
| 2012 | 158.9 | 0.64 | 0.038 |
| 2013 | 120.4 | 0.48 | 0.029 |
| 2014 | 128.0 | 0.51 | 0.031 |
| 2015 | 135.4 | 0.54 | 0.032 |
| 2016 | 140.3 | 0.56 | 0.034 |
| 2017 | 134.1 | 0.54 | 0.032 |
| 2018 | 119.2 | 0.48 | 0.029 |

As seen in Figure 7.3, Figure 7.4 and Figure 7.5, the fluctuations of $CH_4$ and $N_2O$ emissions from composting depend mainly on the fluctuations of the amount of waste treated by composting plants (AD). Emissions were relatively stable between 1990 and 2000 due to the same number of operating facilities during that period. A remarkable increase was observed when the dominant facility became operational after 2001. The fluctuations in recent years were observed due to the changes of the numbers of the active facilities operating those years, as provided in Table 7.23.

$CH_4$ emissions have a maximum value of 0.88 kt in 2003 while having a minimum value of 0.31 kt in 1995. Likewise, $N_2O$ emissions have a maximum value of 0.053 kt in 2003 while having a minimum value of 0.019 kt in 1995.

**Figure 7.3 Amount of waste treated by composting plants, 1990-2018**

**Figure 7.4 $CH_4$ emissions from composting, 1990-2018**

**Figure 7.5 $N_2O$ emissions from composting, 1990-2018**

### Uncertainties and Time-Series Consistency:

The uncertainty value for AD is estimated as 10.0% based on *Table 3.5 in the 2006 IPCC Guidelines, Volume 5, Chapter 3*. The uncertainty value of the EF is considered as 20.0% for both $CH_4$ and $N_2O$ EFs since there is no sufficient information in 2006 IPCC.

The Biological treatment of solid waste category employed a Monte Carlo uncertainty analysis which causes a combined uncertainty range ±22.2% for $CH_4$ emissions and +50% for $N_2O$ emissions in 2019 submission. Detailed explanation of Approach 2 method is in Uncertainty part of this inventory report (Annex 2).

The estimates are calculated in a consistent manner over time series.

### Source-Specific QA/QC and Verification:

QA/QC procedures implemented for each category in order to verify and improve the inventory under the Turkey's QA/QC plan.

The data used in Biological Treatment of Solid Waste (CRF Category 5.B) are derived from waste statistics database of TurkStat. TurkStat is producing all its statistics according to the European Code of Practice Principles. Therefore, high quality data are used in the emission estimates of this category.

Moreover, QA work was conducted by an external reviewer (expert from CITEPA - Technical Reference Center for Air Pollution and Climate Change - in France) for this category in December 2019.

### Recalculation:

In order to provide a complete, consistent and more accurate time series, a detailed study had been carried out during 2019. All survey results are examined and questions were asked to experts on the subject. Therefore, entire time series between 1990-2017 is recalculated according to the background information of AD which is explained in detail under the title of 'Collection of Activity Data'.

Compared to previous inventory submission; in 2017, $CH_4$ emissions increased by 64% (5.2 kt $CO_2$ eq.) likewise $N_2O$ emissions increased by 64% (3.7 kt $CO_2$ eq.) while in 1990, recalculations result with a decrease of 16.5% for both gases, 1.9 kt $CO_2$ eq. for $CH_4$ and 1.3 kt $CO_2$ eq. for $N_2O$.

### Planned Improvement:

Emissions and amount of $CH_4$ for energy recovery from anaerobic digestion at biogas facilities (5.B.2) will be included in next inventory submissions depending on the availability of such treatment processes. Turkey continues to monitor the available waste statistics and any other information to determine the existence of biogas facilities with anaerobic digestion. At this time, no such information exists, but when it becomes available, Turkey intends to estimate these emissions.

## 7.4. Incineration and Open Burning of Waste (Category 5.C)

### Source Category Description:

This category includes emissions from open burning of waste. The category covers $CO_2$, $CH_4$ and $N_2O$ emissions from open burning of waste (5.C.2) which is divided into waste of biogenic origin (5.C.2.1) and waste of non-biogenic origin (5.C.2.2). Only municipal solid waste is open burned in Turkey (5.C.2.2.a). $CO_2$ emissions from waste of biogenic origin are reported but not counted as part of the national total GHG emissions. Unlike $CO_2$, emissions of $CH_4$ and $N_2O$ from biogenic derived wastes are estimated and accounted for under the waste sector.

Emissions from waste incineration (5.C.1) are included in the inventory but reported in the energy sector since the purpose of waste incineration is for energy recovery. Emissions from MSW of biogenic origin (5.C.1.1.a) and MSW of non-biogenic origin (5.C.1.2.a) are not occurring since MSW is not incinerated in the incineration plants in Turkey.

Emissions from incineration of industrial solid waste of biogenic origin (5.C.1.1.b.i) and industrial solid waste of non-biogenic origin (5.C.1.2.b.i) are included in public electricity and heat production (1.A.1.a), chemicals (1.A.2.c) and other (1.A.2.g) sub-categories in the energy sector.

Emissions from incineration of clinical waste of biogenic origin (5.C.1.1.b.ii) and clinical waste of non-biogenic origin (5.C.1.2.b.ii) are included in public electricity and heat production (1.A.1.a).

Emissions from open burning of waste declined 97.7% (102.7 kt $CO_2$ eq.) between 1990 to 2018. The main reason of this negative trend is the decreasing amount of waste open-burned by years, especially with a sharp decline in 2014 after the law of Ministry of Environment and Urbanization.

### Methodological Issues:

The IPCC Tier 2a method recommended in the 2006 IPCC Guidelines for National GHG Inventories is applied to estimate $CO_2$ emissions. As elaborated below, Turkey multiplies the amount of waste types open-burned (wet weight) by the dry matter content, the fossil carbon fraction and an oxidation factor. To estimate $CH_4$ and $N_2O$ emissions, IPCC default emission factors are multiplied by the amount of waste open-burned (the IPCC T1 method in the 2006 IPCC Guidelines).

**$CO_2$ Emissions**

The $CO_2$ emissions from open burning of waste are estimated on the basis of waste types/material (such as paper, wood, plastics) in the waste open-burned as given in *Equation 5.2 in the 2006 IPCC Guidelines, Volume 5, Chapter 5.*

$$CO_2\ Emissions = MSW \bullet \sum_j \left(WF_j \bullet dm_j \bullet CF_j \bullet FCF_j \bullet OF_j\right) \bullet 44/12$$

Where:

$CO_2$ Emissions = $CO_2$ emissions in inventory year, Gg/yr

MSW = total amount of municipal solid waste as wet weight open-burned, Gg/yr

$WF_j$ = fraction of waste type/material of component j in the MSW (as wet weight open-burned)

$dm_j$ = dry matter content in the component j of the MSW open-burned, (fraction)

$CF_j$ = fraction of carbon in the dry matter (i.e., carbon content) of component j

$FCF_j$ = fraction of fossil carbon in the total carbon of component j

$OF_j$ = oxidation factor, (fraction)

44/12 = conversion factor from C to $CO_2$

j = component of the MSW open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

The biogenic $CO_2$ emissions from open burning should not be included in national total emission estimates according to the information given in *2006 IPCC, Volume 5, Chapter 5, Section 5.1* as in Table 7.25. Total $CO_2$ emissions from open burning fluctuate between 1990-2018 as shown in Figure 7.6.

**Table 7.25 $CO_2$ emissions from open burning of waste, 1990-2018**

**(kt)**

| Year | Total | Biogenic | Non-biogenic |
|---|---|---|---|
| 1990 | 26.59 | 0.288 | 26.59 |
| 1991 | 27.18 | 0.281 | 27.18 |
| 1992 | 27.81 | 0.271 | 27.81 |
| 1993 | 28.78 | 0.230 | 28.78 |
| 1994 | 28.64 | 0.285 | 28.64 |
| 1995 | 25.96 | 0.285 | 25.96 |
| 1996 | 27.77 | 0.334 | 27.77 |
| 1997 | 39.22 | 0.514 | 39.22 |
| 1998 | 23.97 | 0.340 | 23.97 |
| 1999 | 21.51 | 0.329 | 21.51 |
| 2000 | 20.98 | 0.345 | 20.98 |
| 2001 | 20.62 | 0.363 | 20.62 |
| 2002 | 13.09 | 0.246 | 13.09 |
| 2003 | 15.17 | 0.303 | 15.17 |
| 2004 | 6.90 | 0.128 | 6.90 |
| 2005 | 11.87 | 0.235 | 11.87 |
| 2006 | 13.80 | 0.347 | 13.80 |
| 2007 | 16.91 | 0.320 | 16.91 |
| 2008 | 17.38 | 0.287 | 17.38 |
| 2009 | 15.24 | 0.220 | 15.24 |
| 2010 | 11.21 | 0.142 | 11.21 |
| 2011 | 14.09 | 0.123 | 14.09 |
| 2012 | 14.42 | 0.088 | 14.42 |
| 2013 | 7.37 | 0.045 | 7.37 |
| 2014 | 0.48 | 0.003 | 0.48 |
| 2015 | 1.07 | 0.006 | 1.07 |
| 2016 | 1.84 | 0.011 | 1.84 |
| 2017 | 1.54 | 0.009 | 1.54 |
| 2018 | 1.24 | 0.006 | 1.24 |

**Figure 7.6 $CO_2$ emissions from open burning of waste, 1990-2018**

**$CH_4$ Emissions**

The calculation of $CH_4$ emissions is based on the amount of waste open-burned and on the related emission factor as given in *Equation 5.4 in the 2006 IPCC Guidelines, Volume 5, Chapter 5.*

$$CH_4\ Emissions = \sum_i (IW_i \bullet EF_i) \bullet 10^{-6}$$

Where:

$CH_4$ Emissions = $CH_4$ emissions in inventory year, Gg/yr

$IW_i$ = amount of solid waste of type i open-burned, Gg/yr

$EF_i$ = aggregate CH4 emission factor, kg $CH_4$/Gg of waste

$10^{-6}$ = conversion factor from kilogram to gigagram

i = category or type of waste open-burned, specified as follows:

MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste,

CW: clinical waste, SS: sewage sludge, others (that must be specified)

Estimated results of $CH_4$ emissions are given in Table 7.26 and Figure 7.7. The $CH_4$ emissions show a decreasing trend with the same fluctuations as with AD between 1990 and 2018 as can be seen in Figure 7.9 below.

**Table 7.26 $CH_4$ emissions from open burning of waste, 1990-2018**

(kt)

| Year | Total | Biogenic | Non-biogenic |
|---|---|---|---|
| 1990 | 2.69 | 1.81 | 0.88 |
| 1991 | 2.74 | 1.85 | 0.89 |
| 1992 | 2.78 | 1.90 | 0.88 |
| 1993 | 2.83 | 1.98 | 0.85 |
| 1994 | 2.87 | 1.95 | 0.92 |
| 1995 | 2.63 | 1.76 | 0.87 |
| 1996 | 2.85 | 1.88 | 0.97 |
| 1997 | 4.06 | 2.64 | 1.42 |
| 1998 | 2.51 | 1.61 | 0.90 |
| 1999 | 2.28 | 1.43 | 0.84 |
| 2000 | 2.25 | 1.39 | 0.85 |
| 2001 | 2.23 | 1.36 | 0.87 |
| 2002 | 1.43 | 0.86 | 0.57 |
| 2003 | 1.68 | 0.99 | 0.69 |
| 2004 | 0.66 | 0.38 | 0.29 |
| 2005 | 1.18 | 0.67 | 0.52 |
| 2006 | 1.60 | 0.88 | 0.72 |
| 2007 | 1.64 | 0.93 | 0.71 |
| 2008 | 1.56 | 0.90 | 0.66 |
| 2009 | 1.27 | 0.74 | 0.53 |
| 2010 | 0.87 | 0.52 | 0.35 |
| 2011 | 0.79 | 0.51 | 0.29 |
| 2012 | 0.68 | 0.46 | 0.22 |
| 2013 | 0.36 | 0.24 | 0.12 |
| 2014 | 0.03 | 0.02 | 0.01 |
| 2015 | 0.04 | 0.03 | 0.01 |
| 2016 | 0.07 | 0.05 | 0.02 |
| 2017 | 0.05 | 0.04 | 0.02 |
| 2018 | 0.04 | 0.03 | 0.01 |

**Figure 7.7 $CH_4$ emissions from open burning of waste, 1990-2018**

**$N_2O$ Emissions**

The calculation of $N_2O$ emissions is based on the amount of waste open-burned and a default emission factor as given in *Equation 5.5 in the 2006 IPCC Guidelines, Volume 5, Chapter 5.*

$$N_2O\ Emissions = \sum_i (IW_i \bullet EF_i) \bullet 10^{-6}$$

Where:

$N_2O$ Emissions = $N_2O$ emissions in inventory year, Gg/yr

$IW_i$ = amount of open-burned waste of type i, Gg/yr

$EF_i$ = $N_2O$ emission factor (kg $N_2O$/Gg of waste) for waste of type i

$10^{-6}$ = conversion from kilogram to gigagram

i = category or type of waste open-burned, specified as follows:

MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste,

CW: clinical waste, SS: sewage sludge, others (that must be specified)

Estimated results of $N_2O$ emissions from open burning of waste are given in Table 7.27 and Figure 7.8. As with $CH_4$ emissions, $N_2O$ emissions have a decreasing trend with the same fluctuations as of AD between 1990 and 2018 as can be seen in Figure 7.9 below.

**Table 7.27 $N_2O$ emissions from open burning of waste, 1990-2018**

(kt)

| Year | Total | Biogenic | Non-biogenic |
|---|---|---|---|
| 1990 | 0.0377 | 0.0191 | 0.0185 |
| 1991 | 0.0381 | 0.0195 | 0.0186 |
| 1992 | 0.0384 | 0.0198 | 0.0185 |
| 1993 | 0.0380 | 0.0202 | 0.0178 |
| 1994 | 0.0397 | 0.0205 | 0.0193 |
| 1995 | 0.0369 | 0.0187 | 0.0182 |
| 1996 | 0.0405 | 0.0202 | 0.0203 |
| 1997 | 0.0586 | 0.0288 | 0.0299 |
| 1998 | 0.0367 | 0.0177 | 0.0190 |
| 1999 | 0.0337 | 0.0160 | 0.0177 |
| 2000 | 0.0337 | 0.0158 | 0.0179 |
| 2001 | 0.0340 | 0.0157 | 0.0183 |
| 2002 | 0.0221 | 0.0100 | 0.0121 |
| 2003 | 0.0262 | 0.0117 | 0.0145 |
| 2004 | 0.0106 | 0.0046 | 0.0060 |
| 2005 | 0.0190 | 0.0082 | 0.0109 |
| 2006 | 0.0263 | 0.0111 | 0.0152 |
| 2007 | 0.0263 | 0.0113 | 0.0150 |
| 2008 | 0.0246 | 0.0107 | 0.0139 |
| 2009 | 0.0198 | 0.0087 | 0.0111 |
| 2010 | 0.0135 | 0.0060 | 0.0075 |
| 2011 | 0.0119 | 0.0057 | 0.0062 |
| 2012 | 0.0098 | 0.0050 | 0.0048 |
| 2013 | 0.0051 | 0.0026 | 0.0026 |
| 2014 | 0.0004 | 0.0002 | 0.0002 |
| 2015 | 0.0006 | 0.0003 | 0.0003 |
| 2016 | 0.0009 | 0.0005 | 0.0004 |
| 2017 | 0.0008 | 0.0004 | 0.0004 |
| 2018 | 0.0006 | 0.0003 | 0.0003 |

**Figure 7.8 $N_2O$ emissions from open burning of waste, 1990-2018**

**Collection of Activity Data**

Activity data for open burning of MSW are estimated using the total amount of MSW open-burned (1994-1998, 2001-2004, 2006, 2008, 2010, 2012, 2014, 2016 and 2018) as obtained from TurkStat's *Municipal Waste Statistics Survey* as given in Table 7.5 and applying an estimate of the composition of MSW.

To calculate the total amount of MSW open-burned for the years not surveyed (1999, 2000, 2005, 2007, 2009, 2011, 2013, 2015 and 2017) the total amount of MSW open-burned as a fraction of the MSW generated data is calculated for the available years (MSW generated data are given in Table 7.8). Open-burned % in generated MSW for the years 1999, 2000, 2005, 2007, 2009, 2011, 2013 and 2015 are estimated by linear interpolation. The open-burned % of 2017 (0.02%) has been recalculated by linear interpolation due to the availability of 2018 survey data. Due to lack of historical data for MSW open-burned, the open-burned % of 1994 (1.89%) is used for 1990-1993. As a result, the total amount of MSW open-burned is calculated for the entire time-series and provided in Table 7.28 and Figure 7.9.

**Table 7.28 The fraction and amount of MSW open-burned, 1990-2018**

| Year | Fraction of MSW open-burned (%) | Amount of MSW open-burned (kt) |
|---|---|---|
| 1990 | 1.89 | 414.22 |
| 1991 | 1.89 | 421.24 |
| 1992 | 1.89 | 428.24 |
| 1993 | 1.89 | 435.21 |
| 1994 | 1.89 | 442.15 |
| 1995 | 1.49 | 405.03 |
| 1996 | 1.49 | 437.90 |
| 1997 | 1.96 | 625.14 |
| 1998 | 1.17 | 386.13 |
| 1999 | 1.15 | 350.34 |
| 2000 | 1.13 | 345.52 |
| 2001 | 1.11 | 343.59 |
| 2002 | 0.71 | 220.55 |
| 2003 | 0.83 | 258.53 |
| 2004 | 0.34 | 101.62 |
| 2005 | 0.58 | 182.05 |
| 2006 | 0.82 | 246.55 |
| 2007 | 0.83 | 252.12 |
| 2008 | 0.84 | 239.29 |
| 2009 | 0.65 | 194.95 |
| 2010 | 0.45 | 133.88 |
| 2011 | 0.40 | 121.98 |
| 2012 | 0.34 | 104.75 |
| 2013 | 0.18 | 54.72 |
| 2014 | 0.01 | 4.28 |
| 2015 | 0.02 | 6.86 |
| 2016 | 0.03 | 10.17 |
| 2017 | 0.02 | 8.18 |
| 2018 | 0.02 | 6.13 |

**Figure 7.9 Total amount of MSW open-burned, 1990-2018**

Country-specific values on the total waste amount (Table 7.28) and the waste fraction for each component for MSW are needed to apply Tier 2a. To calculate the country-specific waste fraction, updated time series of MSW composition data (see Table 7.10) are used as given in Table 7.29. Default dry matter content, total carbon content and fossil carbon fraction of different MSW components are given in Table 7.30 which is based on *Table 2.4 in the 2006 IPCC Guidelines, Volume 5, Chapter 2.*

**Table 7.29 MSW composition data by type of origin, 1990-2018**

**(%)**

| MSW Component | Origin | 1990 | 1991 | 1992 | 1993(1) | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|---|
| Paper/cardboard | Biogenic | 7.9 | 7.6 | 7.2 | 6.0 | 7.3 | 8.0 | 8.7 | 9.3 | 10.0 |
| Textiles | Non-biogenic | 3.8 | 3.8 | 3.9 | 4.0 | 3.9 | 3.8 | 3.7 | 3.7 | 3.6 |
| Food waste | Biogenic | 58.3 | 59.3 | 60.5 | 64.0 | 60.0 | 58.0 | 56.0 | 54.0 | 52.0 |
| Garden and park waste | Biogenic | 1.0 | 0.8 | 0.6 | 0.0 | 0.7 | 1.0 | 1.3 | 1.7 | 2.0 |
| Plastics | Non-biogenic | 2.8 | 2.8 | 2.9 | 3.0 | 2.9 | 2.8 | 2.7 | 2.7 | 2.6 |
| Metal | Non-biogenic | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Glass | Non-biogenic | 2.8 | 2.6 | 2.5 | 2.0 | 2.5 | 2.8 | 3.1 | 3.3 | 3.6 |
| Other, inert waste | Non-biogenic | 22.5 | 22.1 | 21.5 | 20.0 | 21.7 | 22.6 | 23.5 | 24.3 | 25.2 |

(1) TurkStat, Environmental Statistics, Household Solid Waste Composition and Tendency Survey Results, 1993

**Table 7.29 MSW composition data by type of origin, 1990-2018 (Cont.)**

(%)

| MSW Component | Origin | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006(2) | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|
| Paper/cardboard | Biogenic | 10.7 | 11.3 | 12.0 | 12.7 | 13.3 | 14.3 | 14.7 | 16.0 | 14.4 |
| Textiles | Non-biogenic | 3.5 | 3.5 | 3.4 | 3.3 | 3.3 | 3.0 | 3.0 | 3.0 | 3.0 |
| Food waste | Biogenic | 50.0 | 48.0 | 46.0 | 44.0 | 42.0 | 37.2 | 36.5 | 34.0 | 36.9 |
| Garden and park waste | Biogenic | 2.3 | 2.7 | 3.0 | 3.3 | 3.7 | 5.4 | 5.3 | 5.0 | 5.4 |
| Plastics | Non-biogenic | 2.5 | 2.5 | 2.4 | 2.3 | 2.3 | 2.8 | 2.6 | 2.0 | 2.8 |
| Metal | Non-biogenic | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.0 | 1.1 |
| Glass | Non-biogenic | 3.9 | 4.1 | 4.4 | 4.7 | 4.9 | 5.4 | 5.6 | 6.0 | 5.5 |
| Other, inert waste | Non-biogenic | 26.1 | 26.9 | 27.8 | 28.7 | 29.5 | 30.8 | 31.3 | 33.0 | 31.0 |

(2) MoEF, Waste Management Action Plan, 2008-2012

**Table 7.29 MSW composition data by type of origin, 1990-2018 (Cont.)**

(%)

| MSW Component | Origin | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014(3) | 2015 | 2016(4) | 2017(5) | 2018(6) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paper/ cardboard | Biogenic | 13.6 | 12.8 | 12.1 | 11.4 | 9.5 | 9.4 | 8.1 | 10.5 | 11.9 | 11.9 | 10.9 |
| Textiles | Non-biogenic | 3.0 | 3.0 | 3.0 | 2.1 | 1.8 | 1.9 | 2.9 | 1.1 | 0.0 | 0.0 | 0.0 |
| Food waste | Biogenic | 38.4 | 39.9 | 41.4 | 46.3 | 51.1 | 50.8 | 48.7 | 52.4 | 55.1 | 53.8 | 54.6 |
| Garden and park waste | Biogenic | 5.6 | 5.7 | 5.9 | 6.0 | 6.4 | 6.5 | 6.8 | 5.7 | 5.7 | 3.9 | 5.0 |
| Plastics | Non-biogenic | 3.2 | 3.5 | 3.9 | 6.2 | 7.8 | 7.6 | 5.9 | 9.2 | 11.0 | 11.4 | 12.3 |
| Metal | Non-biogenic | 1.1 | 1.1 | 1.2 | 1.5 | 1.7 | 1.7 | 1.4 | 1.9 | 2.3 | 2.3 | 2.2 |
| Glass | Non-biogenic | 5.2 | 5.0 | 4.7 | 4.5 | 3.9 | 3.8 | 3.4 | 4.3 | 4.7 | 5.2 | 5.1 |
| Other, inert waste | Non-biogenic | 30.0 | 28.9 | 27.9 | 21.9 | 17.8 | 18.3 | 22.8 | 14.9 | 9.3 | 11.5 | 9.9 |

(3) MoEU, National Waste Management and Action Plan, 2016-2023

(4), (5), (6) TurkStat, Municipal Waste Statistics Survey Results

**Table 7.30 Default dry matter content, total carbon content and fossil carbon fraction (%)**

| MSW Component | Origin | Dry matter content in % of wet waste | Total carbon content in % of dry weight | Fossil carbon fraction in % of total carbon |
|---|---|---|---|---|
| Paper/cardboard | Biogenic | 90.0 | 46.0 | 1.0 |
| Textiles | Non-biogenic | 80.0 | 50.0 | 20.0 |
| Food waste | Biogenic | 40.0 | 38.0 | - |
| Garden and park waste | Biogenic | 40.0 | 49.0 | 0.0 |
| Plastics | Non-biogenic | 100.0 | 75.0 | 100.0 |
| Metal | Non-biogenic | 100.0 | NA | NA |
| Glass | Non-biogenic | 100.0 | NA | NA |
| Other, inert waste | Non-biogenic | 90.0 | 3.0 | 100.0 |

**Choice of Emission Factor**

Dry matter content (dm), total carbon content (CF) and fossil carbon fraction (FCF) in MSW are calculated using *Equations 5.8, 5.9 and 5.10* respectively as given in the *2006 IPCC Guidelines, Volume 5, Chapter 5.* All different waste fractions (WF) are given in Table 7.29 and the fractions of carbon content given in Table 7.30 above are used related to $CO_2$ emission factors. A default oxidation factor in % of carbon input (OF) is selected for MSW as 58.0%based on *Table 5.2 in 2006 IPCC, Volume 5, Chapter 5*.

The $CH_4$ emissions from open burning of waste are estimated using an EF of 6500 g $CH_4$ / t wet weight for both biogenic and non-biogenic origin of MSW as reported in the *2006 IPCC Guidelines, Volume 5, Chapter 5, Section 5.4.2*.

The $N_2O$ emissions from open burning of waste are estimated using an EF of 150 g $N_2O$ / t dry weight for MSW according to the *2006 IPCC Guidelines, Volume 5, Chapter 5, Table 5.6.* Since the related EF refers to dry weight, the weight of waste open-burned is converted from wet weight to dry weight as reported in the *2006 IPCC Guidelines, Volume 5, Chapter 5, Section 5.3.3* for MSW of both biogenic and non-biogenic origin.

### Uncertainties and Time-Series Consistency:

The uncertainty value for AD is estimated as 30.4%. The uncertainty value of the $CO_2$ EF is considered as 40.0%. Since default values for $CH_4$ and $N_2O$ EFs are used, the uncertainty values of ± 100% are estimated for both EFs as recommended in the *2006 IPCC Guidelines, Volume 5, Chapter 5, Section 5.7.1.*

An uncertainty analysis using the Monte Carlo technique was carried out to estimate emissions of $CO_2$ for 5.C category and also to other waste categories in 2019 inventory year. Combined uncertainty in $CO_2$ emissions in 2017 is estimated at ±41.88%, $CH_4$ emissions is estimated as -85.71% to +114.29% and in $N_2O$ emissions is estimated as -72.73% to +100%. Further information is given in Uncertainty part at the end of this inventory report (Annex 2).

The estimates are calculated in a consistent manner over time series.

**Source-Specific QA/QC and Verification:**

QA/QC procedures are implemented for each category in order to verify and improve the inventory under Turkey's QA/QC plan.

The data used in Incineration and Open Burning of Waste (CRF Category 5.C) are derived from the waste statistics database of TurkStat. TurkStat is producing all its statistics according to the European Code of Practice Principles. Therefore, high quality data are used in the emission estimates of this category.

Moreover, QA work was conducted by an external reviewer (expert from CITEPA - Technical Reference Center for Air Pollution and Climate Change - in France) for this category in December 2019.

**Recalculation:**

2017 data for the fraction of MSW open-burned has been recalculated by linear interpolation due to the availability of 2018 survey data from TurkStat's Municipal Waste Statistics Survey.

There is recalculation for only year 2017. Compared to previous inventory submission; in 2017, $CO_2$ emissions decreased by 19.6% (0.37 kt $CO_2$ eq.), $CH_4$ emissions decreased by 19.6% (0.32 kt $CO_2$ eq.), and $N_2O$ emissions decreased by 19.6% (0.06 kt $CO_2$ eq.).

**Planned Improvement:**

There are no planned improvements in this category.

## 7.5. Wastewater Treatment and Discharge (Category 5.D)

**Source Category Description:**

This category includes $CH_4$ and $N_2O$ emissions from wastewater treatment and discharge systems. Wastewater originates from domestic, commercial and industrial sources by treatment and disposal systems. Because of the IPCC methodology, emissions from commercial wastewater are estimated as

part of domestic wastewater. Treatment and disposal types for domestic and industrial wastewater are separated into collected and uncollected systems. Each system is divided into untreated and treated systems. For collected systems; sea, river and lake discharge, and stagnant sewer are the untreated systems. Aerobic and anaerobic treatments are the main treated systems of sewered to plants. For uncollected systems; septic system is considered as treated and sea, river and lake discharge as untreated practices in Turkey.

$CH_4$ emissions are estimated for both domestic wastewater (5.D.1) and industrial wastewater (5.D.2). $N_2O$ emissions from 5.D.2 are also reported in 5.D.1.

Wastewater treatment and discharge emissions increased by 109.9% (4 647.1 kt $CO_2$ eq.) for the period 1990-2018, also increased by 6.6% (550.4 kt $CO_2$ eq.) between 2017 and 2018. Methane recovery in domestic wastewater treatment increased by 499% (685.2 kt $CO_2$ eq.) between 1998 (137.2 kt $CO_2$ eq.) and 2018 (822.4 kt $CO_2$ eq.).

## Methodological Issues:

### Methane Emissions from Wastewater

### Methane Emissions from Domestic Wastewater

The IPCC T2 method of the 2006 IPCC Guidelines is applied to estimate $CH_4$ emissions from domestic wastewater. $CH_4$ emissions are estimated using *Equation 6.1 in the 2006 IPCC Guidelines, Volume 5, Chapter 6.*

$$CH_4\ Emissions = \left[\sum_{i,j}\left(U_i \bullet T_{i,j} \bullet EF_j\right)\right](TOW - S) - R$$

Where:

$CH_4$ Emissions = $CH_4$ emissions in inventory year, kg $CH_4$/yr

TOW = total organics in wastewater in inventory year, kg BOD/yr

S = organic component removed as sludge in inventory year, kg BOD/yr

$U_i$ = fraction of population in income group in inventory year

$T_{i,j}$= degree of utilisation of treatment/discharge pathway or system, j, for each income group fraction 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

R = amount of $CH_4$ recovered in inventory year, kg $CH_4$/yr

Total $CH_4$ emissions are estimated based on country-specific information on the total organics in wastewater minus the total amount of sludge and multiplying by the IPCC default emission factor, corrected for country-specific fractions of urban/rural populations and the fraction of the wastewater utilizing the various discharge pathways. The amount of methane generated, methane recovered and net methane emissions are estimated as given in Table 7.31 and Figure 7.10.

**Table 7.31 $CH_4$ generated, recovered and emitted from domestic wastewater, 1990-2018**

(kt)

| Year | $CH_4$ Generated | $CH_4$ Recovered | $CH_4$ Emitted |
|---|---|---|---|
| 1990 | 103.2 | NO | 103.2 |
| 1991 | 104.5 | NO | 104.5 |
| 1992 | 105.8 | NO | 105.8 |
| 1993 | 107.1 | NO | 107.1 |
| 1994 | 108.4 | NO | 108.4 |
| 1995 | 109.7 | NO | 109.7 |
| 1996 | 110.9 | NO | 110.9 |
| 1997 | 112.1 | NO | 112.1 |
| 1998 | 113.2 | 5.5 | 107.8 |
| 1999 | 114.4 | 6.2 | 108.2 |
| 2000 | 115.6 | 6.9 | 108.6 |
| 2001 | 116.5 | 7.8 | 108.7 |
| 2002 | 117.4 | 8.5 | 108.8 |
| 2003 | 118.1 | 10.7 | 107.4 |
| 2004 | 118.8 | 9.2 | 109.7 |
| 2005 | 119.6 | 11.9 | 107.7 |
| 2006 | 120.4 | 10.7 | 109.8 |
| 2007 | 121.2 | 14.1 | 107.2 |
| 2008 | 118.8 | 15.5 | 103.3 |
| 2009 | 119.9 | 16.4 | 103.5 |
| 2010 | 121.1 | 16.8 | 104.3 |
| 2011 | 122.4 | 21.3 | 101.0 |
| 2012 | 123.5 | 24.3 | 99.2 |
| 2013 | 111.6 | 24.9 | 86.7 |
| 2014 | 112.7 | 34.0 | 78.7 |
| 2015 | 113.9 | 37.7 | 76.2 |
| 2016 | 115.2 | 38.2 | 77.0 |
| 2017 | 117.3 | 39.6 | 77.7 |
| 2018 | 119.2 | 32.9 | 86.3 |

**Figure 7.10 $CH_4$ emissions from domestic wastewater, 1990-2018**

The key drivers for the decreasing trend in net emissions are the increasing of methane recovery after the beginning year of 1998. Despite having an increasing trend normally, the main reasons for the sharp decreases in generated methane in the years of 2008 and 2013 are the administrative division changes in the proportion of urban and rural population in 2008 and 2013.

**Collection of Activity Data**

To calculate $CH_4$ emissions from domestic wastewater, total organics in wastewater (TOW) and organic component removed as sludge (S) are needed. The TOW is calculated using *Equation 6.3 in the 2006 IPCC Guidelines, Volume 5, Chapter 6.*

$$TOW = P \bullet BOD \bullet 0.001 \bullet I \bullet 365$$

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,

0.001 = conversion from grams BOD to kg BOD

I = correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00.)

The total population is used to calculate TOW and S values. For the entire time series, the total population is taken from Turkstat's *Mid-year Population Estimations and Projections*. The total population is then divided into the rural and urban fractions to better characterize the discharge pathways for the domestic wastewater. For the years 1990 and 2000, rural and urban population are available from *General Population Censuses*. The results of *Address Based Population Registration System* are used from 2007 to 2017 to split the rural and urban population. Rural and urban population fractions are used to interpolate fractions of rural and urban population for the missing years. The figures are given in Table 7.32.

**Table 7.32 Fraction of population and total, rural, urban population, 1990-2018**

| Year | Fraction of rural | Fraction of urban | Total population | Rural population | Urban population |
|---|---|---|---|---|---|
| 1990 | 41.0 | 59.0 | 55 120 000 | 22 592 114 | 32 527 886 |
| 1991 | 40.4 | 59.6 | 56 055 000 | 22 645 221 | 33 409 779 |
| 1992 | 39.8 | 60.2 | 56 986 000 | 22 685 723 | 34 300 277 |
| 1993 | 39.2 | 60.8 | 57 913 000 | 22 713 690 | 35 199 310 |
| 1994 | 38.6 | 61.4 | 58 837 000 | 22 729 580 | 36 107 420 |
| 1995 | 38.0 | 62.0 | 59 756 000 | 22 732 684 | 37 023 316 |
| 1996 | 37.5 | 62.5 | 60 671 000 | 22 723 466 | 37 947 534 |
| 1997 | 36.9 | 63.1 | 61 582 000 | 22 701 996 | 38 880 004 |
| 1998 | 36.3 | 63.7 | 62 464 000 | 22 659 275 | 39 804 725 |
| 1999 | 35.7 | 64.3 | 63 364 000 | 22 612 590 | 40 751 410 |
| 2000 | 35.1 | 64.9 | 64 269 000 | 22 557 058 | 41 711 942 |
| 2001 | 34.3 | 65.7 | 65 166 000 | 22 352 793 | 42 813 207 |
| 2002 | 33.5 | 66.5 | 66 003 000 | 22 114 135 | 43 888 865 |
| 2003 | 32.7 | 67.3 | 66 795 000 | 21 847 423 | 44 947 577 |
| 2004 | 31.9 | 68.1 | 67 599 000 | 21 571 923 | 46 027 077 |
| 2005 | 31.1 | 68.9 | 68 435 000 | 21 293 571 | 47 141 429 |
| 2006 | 30.3 | 69.7 | 69 295 000 | 21 009 177 | 48 285 823 |
| 2007 | 29.5 | 70.5 | 70 158 000 | 20 711 968 | 49 446 032 |
| 2008 | 25.0 | 75.0 | 71 052 000 | 17 788 932 | 53 263 068 |
| 2009 | 24.5 | 75.5 | 72 039 000 | 17 626 295 | 54 412 705 |
| 2010 | 23.7 | 76.3 | 73 142 000 | 17 362 715 | 55 779 285 |
| 2011 | 23.2 | 76.8 | 74 224 000 | 17 222 484 | 57 001 516 |
| 2012 | 22.7 | 77.3 | 75 176 000 | 17 076 420 | 58 099 580 |
| 2013 | 8.7 | 91.3 | 76 148 000 | 6 588 471 | 69 559 529 |
| 2014 | 8.2 | 91.8 | 77 182 000 | 6 367 326 | 70 814 674 |
| 2015 | 7.9 | 92.1 | 78 218 000 | 6 176 615 | 72 041 385 |
| 2016 | 7.7 | 92.3 | 79 278 000 | 6 101 802 | 73 176 198 |
| 2017 | 7.5 | 92.5 | 80 810 525 | 6 049 393 | 74 761 132 |
| 2018 | 7.7 | 92.3 | 82 003 882 | 6 337 385 | 75 666 497 |

The urban population consists of the total population of province and district centers and, rural population consists of the total population of towns and villages. The proportions of the population living in the province and district centers were 91.3% in 2013, 91.8% in 2014, 92.1% in 2015, 92.3% in 2016, 92.5% in 2017 and 92.3% in 2018 while this figure was 77.3% in 2012. The main reason for this sharp

rise was the establishment of 14 new metropolitan municipalities and enlarging the municipal borders by abolition of towns and villages in all of the 30 metropolitan provinces in 2013.

TOW is calculated using a country-specific per capita BOD as 53 g/person/day for wastewater collected by sewers. The source of this BOD is *Derivation of Factors for Pollution Loads Discharged to Receiving Bodies by Municipalities, İpek Turtin Uzer, Turkish Statistical Institute Expertness Thesis, Ankara, 2010*. This study includes a country-specific per capita BOD for receiving bodies as 25 g/person/day. Country-specific per capita BOD for sludge removed is calculated as 28 g/person/day by using these data to be able to calculate organic component removed as sludge (S). Correction factor (I) is taken as the default value of 1.0. TOW and S values for domestic wastewater are calculated as given in Table 7.33.

**Table 7.33 Total organics in wastewater (TOW) and organic component removed as sludge (S) for domestic wastewater, 1990-2018**

| | | (kt BOD/yr) |
|---|---|---|
| **Year** | **TOW** | **S** |
| 1990 | 1 066.3 | 563.3 |
| 1991 | 1 084.4 | 572.9 |
| 1992 | 1 102.4 | 582.4 |
| 1993 | 1 120.3 | 591.9 |
| 1994 | 1 138.2 | 601.3 |
| 1995 | 1 156.0 | 610.7 |
| 1996 | 1 173.7 | 620.1 |
| 1997 | 1 191.3 | 629.4 |
| 1998 | 1 208.4 | 638.4 |
| 1999 | 1 225.8 | 647.6 |
| 2000 | 1 243.3 | 656.8 |
| 2001 | 1 260.6 | 666.0 |
| 2002 | 1 276.8 | 674.6 |
| 2003 | 1 292.1 | 682.6 |
| 2004 | 1 307.7 | 690.9 |
| 2005 | 1 323.9 | 699.4 |
| 2006 | 1 340.5 | 708.2 |
| 2007 | 1 357.2 | 717.0 |
| 2008 | 1 374.5 | 726.2 |
| 2009 | 1 393.6 | 736.2 |
| 2010 | 1 414.9 | 747.5 |
| 2011 | 1 435.9 | 758.6 |
| 2012 | 1 454.3 | 768.3 |
| 2013 | 1 473.1 | 778.2 |
| 2014 | 1 493.1 | 788.8 |
| 2015 | 1 513.1 | 799.4 |
| 2016 | 1 533.6 | 810.2 |
| 2017 | 1 563.3 | 825.9 |
| 2018 | 1 586.4 | 838.1 |

**Choice of Emission Factor**

As given in *Equation 6.2 in the 2006 IPCC Guidelines, Volume 5, Chapter 6*, $CH_4$ EFs for each domestic wastewater treatment/discharge pathway or system are calculated by multiplying the default maximum $CH_4$ producing capacity ($B_o$) for domestic wastewater (0.6 kg $CH_4$/kg BOD) by the methane correction factor (MCF) for each type of treatment and discharge pathway or system, which is given in the *2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.3*.

$$EF_j = B_o \bullet MCF_j$$

Where:

$EF_j$ = emission factor, kg $CH_4$/kg BOD

j = each treatment/discharge pathway or system

$B_o$ = maximum $CH_4$ producing capacity, kg $CH_4$/kg BOD

$MCF_j$ = methane correction factor (fraction)

To calculate country-specific values for the degrees of treatment utilization (T), by population class, the results of TurkStat's *Municipal Wastewater Statistics Survey, 2012* and *Sectoral Water and Wastewater Statistics Survey, 2012* are used. The degrees of utilizations are given in Table 7.34.

**Table 7.34 Degrees of treatment utilization (T) by population class**

| Treatment or discharge system or pathway | | T (%) |
|---|---|---|
| Rural | To sea, river and lake | 0.43 |
| | To aerobic plant, not well managed | 0.44 |
| | To septic systems | 10.72 |
| Urban | To sea, river and lake | 15.43 |
| | To aerobic plant, well managed | 44.01 |
| | To aerobic plant, not well managed | 1.82 |
| | To anaerobic digester for sludge | 20.83 |
| | To septic systems | 6.31 |
| Total | | 100.00 |

Weighted $CH_4$ EFs are calculated using $CH_4$ EFs by each type of treatment and discharge pathway or system and the fractional usage of different treatment systems by population class. Weighted $CH_4$ EFs for domestic wastewater with background data are given in Table 7.35.

**Table 7.35 MCF, EFs, utilization degrees and weighted EFs by population class**

| Type of treatment and discharge path way or system | MCF | $CH_4$ EF | T (Rural) | T (Urban) |
|---|---|---|---|---|
| **Untreated system** | | | | |
| Sea, river, lake discharge | 0.10 | 0.06 | 0.0043 | 0.1543 |
| **Treated system** | | | | |
| Centralized, aerobic, well managed | 0.00 | 0.00 | | 0.4401 |
| Centralized, aerobic, not well managed | 0.30 | 0.18 | 0.0044 | 0.0182 |
| Anaerobic digester for sludge | 0.80 | 0.48 | | 0.2083 |
| Septic system | 0.50 | 0.30 | 0.1072 | 0.0631 |
| **Total** | | | **0.12** | **0.88** |
| **Weighted $CH_4$ EFs (kg $CH_4$/kg BOD)** | | | **0.29** | **0.15** |

**Methane Recovery**

The recovery of methane and its subsequent utilization is also considered in the inventory. Methane recovery from biogas started to be implemented in Turkey in 1998. Therefore, the quantity of recovered methane is subtracted from the methane produced beginning in the year 1998. In 2013, *Municipal Wastewater Statistics Survey, 2012* was applied to all municipalities. Based on the information obtained from the survey, TurkStat sends official letters to each facility recovering methane for requesting the quantity of methane gas and electricity production for the entire operating period of the facility every year. The facilities estimate the quantity of methane recovered by measuring of gas recovered. The obtained information on the quantity of produced electricity is used for cross-check of the quantity of methane recovered.

The coverage of the facilities is followed and updated depending on availability of new information; including information obtained from the facility, the information from the latest (biennial) survey *(Municipal Wastewater Statistics Survey, 2018)* etc. The emissions of energy production from the recovered $CH_4$ gas in biogas facilities were included in the category of Public Electricity and Heat Production (1.A.1.a).

The number of biogas facilities and the amount of recovered methane by year are given in Table 7.36.

**Table 7.36 Methane recovery, 1990-2018**

| Year | Number of biogas facilities | Recovered methane (kt) |
|---|---|---|
| 1990-97 | NA | NO |
| 1998 | 1 | 5.5 |
| 1999 | 1 | 6.2 |
| 2000 | 1 | 6.9 |
| 2001 | 2 | 7.8 |
| 2002 | 2 | 8.5 |
| 2003 | 2 | 10.7 |
| 2004 | 3 | 9.2 |
| 2005 | 4 | 11.9 |
| 2006 | 4 | 10.7 |
| 2007 | 7 | 14.1 |
| 2008 | 7 | 15.5 |
| 2009 | 7 | 16.4 |
| 2010 | 8 | 16.8 |
| 2011 | 13 | 21.3 |
| 2012 | 14 | 24.3 |
| 2013 | 18 | 24.9 |
| 2014 | 19 | 34.0 |
| 2015 | 20 | 37.7 |
| 2016 | 23 | 38.2 |
| 2017 | 23 | 39.6 |
| 2018 | 28 | 32.9 |

**Sewage Sludge Balance**

Sewage sludge is domestic wastewater treatment sludge originating from urban wastewater treatment plants operated by municipalities. Thus, the sewage sludge data are collected by TurkStat from Municipal Wastewater Statistics Survey which is applied to all municipalities. Data on the amount of sludge is compiled on a wet basis and converted to dry matter using coefficients in the guidance documents of the European Union Statistical Office (EUROSTAT). Also, data are compiled in accordance with the OECD / EUROSTAT - Wastewater statistics, environmental data and indicators data set.

As mentioned in Solid Waste Disposal section (Category 5.A), the disposal methods named 'Dumping on to land', 'Municipal dumping sites', 'Controlled landfill sites', 'Buried' and 'Other' are added together and assumed as the total sludge that stored in SWDS.

For the sewage sludge balance, the amount of sewage sludge by disposal and recovery methods, please refer to Table 7.37.

However, domestic wastewater treatment sludge is not estimated throughout the data in Table 7.37. It is still estimated over BOD calculation with population data likewise the estimation of TOW values.

**Table 7.37 Amount of sewage sludge by disposal and recovery methods, 1990-2018**

(t)

| Year | Agricultural use | Released into sea | Dumping onto land | Municipal dumping sites | Released into lake | Released into river | Incineration with energy recovery | Controlled landfill sites | Buried | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| 1994 | 12 546 | 321 | 0 | 772 | 0 | 0 | 0 | 722 | 0 | 26 |
| 1995 | 13 309 | 10 | 150 | 1 783 | 0 | 0 | 0 | 0 | 0 | 56 |
| 1996 | 12 322 | 0 | 40 | 1 931 | 0 | 0 | 0 | 20 | 10 | 2 |
| 1997 | 34 397 | 0 | 0 | 1 871 | 0 | 0 | 0 | 26 | 2 | 112 |
| 1998 | 49 555 | 0 | 2 029 | 10 125 | 297 | 0 | 0 | 6 627 | 487 | 0 |
| 2001 | 47 152 | 54 | 45 | 28 356 | 50 | 7 300 | 0 | 40 431 | 1 500 | 467 |
| 2002 | 26 445 | 1 095 | 274 | 31 189 | 4 | 0 | 1 | 55 789 | 8 378 | 37 560 |
| 2003 | 91 104 | 0 | 521 | 13 218 | 180 | 0 | 0 | 57 518 | 10 302 | 0 |
| 2004 | 81 795 | 0 | 2 760 | 12 345 | 48 | 1 000 | 0 | 92 085 | 2 154 | 36 128 |
| 2006 | 12 512 | 0 | 2 954 | 65 044 | 20 000 | 2 161 | 0 | 85 606 | 38 281 | 31 772 |
| 2008 | 17 118 | 0 | 9 480 | 58 026 | 0 | 3 074 | 2 082 | 104 846 | 12 890 | 67 350 |
| 2010 | 12 433 | 0 | 10 112 | 92 741 | 0 | 2 018 | 13 020 | 98 843 | 10 243 | 71 402 |
| 2012 | 11 412 | 0 | 19 456 | 107 989 | 0 | 22 | 29 952 | 101 143 | 2 517 | 45 906 |
| 2014 | 10 255 | 0 | 39 637 | 41 214 | 0 | 105 | 53 486 | 91 539 | 4 670 | 46 884 |
| 2016 | 9 261 | 0 | 7 023 | 62 733 | 0 | 0 | 93 939 | 83 005 | 278 | 43 057 |
| 2018 | 10 349 | 0 | 6 710 | 36 135 | 5 | 10 | 71 568 | 85 382 | 4 464 | 32 591 |

Source: TurkStat, Municipal Wastewater Statistics
Note: Data on sludge amount is in dry matter.

**Methane Emissions from Industrial Wastewater**

This section deals with estimating $CH_4$ emissions from on-site industrial wastewater treatment. The IPCC T2 method of the 2006 IPCC Guidelines is applied to estimate $CH_4$ emissions from industrial wastewater. $CH_4$ emissions are estimated using *Equation 6.4 in the 2006 IPCC Guidelines, Volume 5, Chapter 6.*

$$CH_4\ Emissions = \sum_i [(TOW_i - S_i)\ EF_i - R_i]$$

Where:

$CH_4$ Emissions = $CH_4$ emissions in inventory year, kg $CH_4$/yr

$TOW_i$ = total organically degradable material in wastewater from industry i in inventory year, kg COD/yr

i = industrial sector

$S_i$ = organic component removed as sludge in inventory year, kg COD/yr

$EF_i$ = emission factor for industry i, kg $CH_4$/kg COD

for treatment/discharge pathway or system(s) used in inventory year

$R_i$ = amount of $CH_4$ recovered in inventory year, kg $CH_4$/yr

Specifically, the country-specific information on the total organically degradable material in wastewater, by industry, is multiplied by a specific emission factor that takes into account the relative use of various treatment/discharge pathways. There is no recovery of methane from industrial wastewater and sludge removal is assumed to be zero. Amount of methane emissions, by industry, are estimated as given in Table 7.38 and Figure 7.11.

**Table 7.38 $CH_4$ emissions from industrial wastewater by sector, 1990-2018**

(kt)

| Year | Total | Meat & poultry | Organic chemicals | Petroleum refineries | Plastics & resins | Pulp & paper (combined) | Starch production |
|---|---|---|---|---|---|---|---|
| 1990-94 | 8.37 | 1.37 | 0.54 | 0.12 | 0.70 | 4.56 | 1.09 |
| 1995 | 12.01 | 1.79 | 1.62 | 0.12 | 0.75 | 5.43 | 2.29 |
| 1996 | 11.53 | 1.97 | 0.66 | 0.15 | 0.65 | 5.01 | 3.09 |
| 1997 | 15.25 | 2.12 | 0.78 | 0.15 | 1.10 | 6.32 | 4.78 |
| 1998 | 14.44 | 1.90 | 1.31 | 0.15 | 0.90 | 5.73 | 4.45 |
| 1999 | 13.63 | 1.68 | 1.85 | 0.15 | 0.69 | 5.14 | 4.12 |
| 2000 | 12.82 | 1.47 | 2.38 | 0.15 | 0.48 | 4.55 | 3.80 |
| 2001 | 13.38 | 1.59 | 2.08 | 0.15 | 0.77 | 3.68 | 5.12 |
| 2002 | 13.95 | 1.71 | 1.79 | 0.15 | 1.05 | 2.80 | 6.44 |
| 2003 | 14.52 | 1.84 | 1.50 | 0.15 | 1.34 | 1.93 | 7.76 |
| 2004 | 15.10 | 1.96 | 1.21 | 0.14 | 1.63 | 1.08 | 9.08 |
| 2005 | 14.80 | 1.90 | 1.03 | 0.13 | 1.54 | 1.25 | 8.96 |
| 2006 | 14.51 | 1.84 | 0.85 | 0.11 | 1.46 | 1.42 | 8.84 |
| 2007 | 14.21 | 1.77 | 0.67 | 0.09 | 1.37 | 1.59 | 8.72 |
| 2008 | 14.27 | 2.02 | 0.53 | 0.07 | 1.30 | 1.75 | 8.60 |
| 2009 | 14.29 | 2.03 | 0.44 | 0.09 | 1.22 | 2.08 | 8.43 |
| 2010 | 14.32 | 2.03 | 0.36 | 0.11 | 1.14 | 2.41 | 8.26 |
| 2011 | 16.50 | 2.42 | 0.50 | 0.15 | 1.99 | 2.52 | 8.91 |
| 2012 | 18.68 | 2.81 | 0.63 | 0.19 | 2.84 | 2.64 | 9.57 |
| 2013 | 18.85 | 2.79 | 0.67 | 0.19 | 2.88 | 2.74 | 9.58 |
| 2014 | 19.02 | 2.76 | 0.71 | 0.19 | 2.92 | 2.85 | 9.60 |
| 2015 | 20.00 | 3.24 | 1.03 | 0.20 | 2.98 | 2.82 | 9.72 |
| 2016 | 20.97 | 3.72 | 1.34 | 0.22 | 3.05 | 2.79 | 9.84 |
| 2017 | 23.04 | 4.00 | 1.34 | 0.24 | 3.50 | 2.93 | 11.04 |
| 2018 | 25.11 | 4.27 | 1.34 | 0.25 | 3.95 | 3.06 | 12.23 |

**Figure 7.11 $CH_4$ emissions from industrial wastewater, 1990-2018**

**Collection of Activity Data**

To calculate $CH_4$ emissions from industrial wastewater, total organically degradable material in wastewater for each industry ($TOW_i$) is used as AD and calculated by applying *Equation 6.6 in the 2006 IPCC Guidelines, Volume 5, Chapter 6.*

$$TOW_i = P_i \bullet W_i \bullet COD_i$$

Where:

$TOW_i$ = 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, $m^3/t_{product}$

$COD_i$ = chemical oxygen demand (industrial degradable organic component in wastewater), kg COD/$m^3$

Organic component removed as sludge (S) is assumed to be zero in the inventory years. The amount of industrial wastewater treated for the following major industrial sectors are obtained from TurkStat's *Manufacturing Industry Establishments Water Wastewater and Waste Statistics Survey* for the years 1994-1997, 2000, 2004, 2008, 2010, 2012, 2014, 2016 and 2018. Missing data for the years not surveyed (1998, 1999, 2001-2003, 2005-2007, 2009, 2011, 2013 and 2015) are estimated by linear interpolation. For more accurate activity data, 2017 AD of previous submission has been recalculated by interpolation method due to the availability of 2018 AD.

The amount of industrial wastewater treated by industrial sectors are given in Table 7.39.

**Table 7.39 Amount of industrial wastewater discharged by sector, 1990-2018**

**(thousand $m^3$/yr)**

| Year | Total | Meat & poultry | Organic chemicals | Petroleum refineries | Plastics & resins | Pulp & paper (combined) | Starch production |
|---|---|---|---|---|---|---|---|
| 1990-94 | 110 753 | 25 749 | 13 771 | 9 155 | 14 574 | 39 072 | 8 432 |
| 1995 | 164 593 | 33 752 | 41 583 | 9 239 | 15 739 | 46 583 | 17 697 |
| 1996 | 145 711 | 37 124 | 16 875 | 11 393 | 13 479 | 42 956 | 23 884 |
| 1997 | 185 827 | 39 935 | 20 148 | 11 704 | 23 001 | 54 176 | 36 863 |
| 1998 | 183 379 | 35 820 | 33 812 | 11 610 | 18 672 | 49 121 | 34 344 |
| 1999 | 180 932 | 31 706 | 47 475 | 11 517 | 14 343 | 44 066 | 31 825 |
| 2000 | 178 484 | 27 591 | 61 139 | 11 423 | 10 014 | 39 011 | 29 306 |
| 2001 | 181 945 | 29 936 | 53 629 | 11 355 | 16 004 | 31 527 | 39 494 |
| 2002 | 185 406 | 32 281 | 46 118 | 11 288 | 21 995 | 24 044 | 49 682 |
| 2003 | 188 867 | 34 625 | 38 608 | 11 220 | 27 985 | 16 560 | 59 870 |
| 2004 | 192 492 | 36 970 | 31 097 | 11 152 | 33 975 | 9 240 | 70 058 |
| 2005 | 184 002 | 35 758 | 26 501 | 9 728 | 32 198 | 10 691 | 69 127 |
| 2006 | 175 512 | 34 545 | 21 904 | 8 305 | 30 421 | 12 143 | 68 196 |
| 2007 | 167 022 | 33 333 | 17 308 | 6 881 | 28 643 | 13 594 | 67 264 |
| 2008 | 165 487 | 38 049 | 13 515 | 5 457 | 27 088 | 15 045 | 66 333 |
| 2009 | 164 901 | 38 165 | 11 443 | 6 939 | 25 475 | 17 837 | 65 042 |
| 2010 | 164 314 | 38 282 | 9 372 | 8 421 | 23 862 | 20 628 | 63 750 |
| 2011 | 201 980 | 45 624 | 12 791 | 11 620 | 41 503 | 21 649 | 68 792 |
| 2012 | 239 646 | 52 967 | 16 211 | 14 819 | 59 145 | 22 670 | 73 834 |
| 2013 | 241 879 | 52 494 | 17 277 | 14 636 | 59 995 | 23 535 | 73 944 |
| 2014 | 244 112 | 52 020 | 18 342 | 14 452 | 60 844 | 24 399 | 74 054 |
| 2015 | 264 574 | 61 040 | 26 429 | 15 670 | 62 250 | 24 180 | 75 005 |
| 2016 | 285 035 | 70 059 | 34 516 | 16 887 | 63 655 | 23 961 | 75 956 |
| 2017 | 311 203 | 75 216 | 34 445 | 18 197 | 73 063 | 25 116 | 85 165 |
| 2018 | 337 372 | 80 374 | 34 374 | 19 507 | 82 471 | 26 271 | 94 375 |

$TOW_i$ is calculated by applying COD values for each industrial sector as given in Table 7.40, that are based on *Table 6.9 in the 2006 IPCC Guidelines, Volume 5, Chapter 6* and the results are given in Table 7.41.

**Table 7.40 COD values by industry type**

| Industry type | COD (kg/m$^3$) |
|---|---|
| Meat & Poultry | 4.1 |
| Organic Chemicals | 3.0 |
| Petroleum Refineries | 1.0 |
| Plastics & Resins | 3.7 |
| Pulp & Paper (combined) | 9.0 |
| Starch Production | 10.0 |

**Table 7.41 TOW$_i$ in wastewater by industry sector, 1990-2018**

(kt COD/yr)

| Year | Total | Meat & poultry | Organic chemicals | Petroleum refineries | Plastics & resins | Pulp & paper (combined) | Starch production |
|---|---|---|---|---|---|---|---|
| 1990-94 | 645.9 | 105.6 | 41.3 | 9.2 | 53.9 | 351.6 | 84.3 |
| 1995 | 926.8 | 138.4 | 124.7 | 9.2 | 58.2 | 419.2 | 177.0 |
| 1996 | 889.5 | 152.2 | 50.6 | 11.4 | 49.9 | 386.6 | 238.8 |
| 1997 | 1 177.2 | 163.7 | 60.4 | 11.7 | 85.1 | 487.6 | 368.6 |
| 1998 | 1 114.5 | 146.9 | 101.4 | 11.6 | 69.1 | 442.1 | 343.4 |
| 1999 | 1 051.8 | 130.0 | 142.4 | 11.5 | 53.1 | 396.6 | 318.3 |
| 2000 | 989.2 | 113.1 | 183.4 | 11.4 | 37.1 | 351.1 | 293.1 |
| 2001 | 1 032.9 | 122.7 | 160.9 | 11.4 | 59.2 | 283.7 | 394.9 |
| 2002 | 1 076.6 | 132.4 | 138.4 | 11.3 | 81.4 | 216.4 | 496.8 |
| 2003 | 1 120.3 | 142.0 | 115.8 | 11.2 | 103.5 | 149.0 | 598.7 |
| 2004 | 1 165.5 | 151.6 | 93.3 | 11.2 | 125.7 | 83.2 | 700.6 |
| 2005 | 1 142.5 | 146.6 | 79.5 | 9.7 | 119.1 | 96.2 | 691.3 |
| 2006 | 1 119.4 | 141.6 | 65.7 | 8.3 | 112.6 | 109.3 | 682.0 |
| 2007 | 1 096.4 | 136.7 | 51.9 | 6.9 | 106.0 | 122.3 | 672.6 |
| 2008 | 1 101.0 | 156.0 | 40.5 | 5.5 | 100.2 | 135.4 | 663.3 |
| 2009 | 1 102.9 | 156.5 | 34.3 | 6.9 | 94.3 | 160.5 | 650.4 |
| 2010 | 1 104.9 | 157.0 | 28.1 | 8.4 | 88.3 | 185.7 | 637.5 |
| 2011 | 1 273.4 | 187.1 | 38.4 | 11.6 | 153.6 | 194.8 | 687.9 |
| 2012 | 1 441.8 | 217.2 | 48.6 | 14.8 | 218.8 | 204.0 | 738.3 |
| 2013 | 1 454.9 | 215.2 | 51.8 | 14.6 | 222.0 | 211.8 | 739.4 |
| 2014 | 1 468.0 | 213.3 | 55.0 | 14.5 | 225.1 | 219.6 | 740.5 |
| 2015 | 1 543.2 | 250.3 | 79.3 | 15.7 | 230.3 | 217.6 | 750.1 |
| 2016 | 1 618.4 | 287.2 | 103.5 | 16.9 | 235.5 | 215.7 | 759.6 |
| 2017 | 1 778.0 | 308.4 | 103.3 | 18.2 | 270.3 | 226.0 | 851.7 |
| 2018 | 1 937.5 | 329.5 | 103.1 | 19.5 | 305.1 | 236.4 | 943.7 |

### Choice of Emission Factor

As given in *Equation 6.5 in the 2006 IPCC Guidelines, Volume 5, Chapter 6*, $CH_4$ EFs for each industrial wastewater treatment/discharge pathway or system are calculated by multiplying the default maximum

$CH_4$ producing capacity ($B_o$) for industrial wastewater (0.25 kg $CH_4$/kg COD) by the methane correction factor (MCF) for each type of treatment and discharge pathway or system which is given in the *2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.8.*,

$$EF_j = B_o \bullet MCF_j$$

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 $CH_4$/kg COD

$MCF_j$ = methane correction factor (fraction)

Weighted $CH_4$ EFs are calculated by multiplying $CH_4$ EFs for each type of treatment and discharge pathway or system and fractional usage of the different treatment systems. Weighted $CH_4$ EF for industrial wastewater with background data are given in Table 7.42.

**Table 7.42 MCF, EFs, fractional usages and weighted EF for industrial wastewater**

| Type of treatment and discharge pathway or system | MCF | $CH_4$ EF | Fractional usage |
|---|---|---|---|
| **Untreated system** | | | |
| Sea, river, lake discharge | 0.10 | 0.03 | 0.173 |
| **Treated system** | | | |
| Aerobic treatment plant, well managed | 0.00 | 0.00 | 0.668 |
| Aerobic treatment plant, not well managed | 0.30 | 0.08 | 0.088 |
| Anaerobic digester for sludge | 0.80 | 0.20 | 0.025 |
| Anaerobic reactor | 0.80 | 0.20 | 0.030 |
| Septic system | 0.50 | 0.13 | 0.016 |
| **Total** | | | **1.00** |
| **Weighted $CH_4$ EF (kg $CH_4$/kg COD)** | | | **0.01** |

**Nitrous Oxide Emissions from Wastewater**

Turkey applies the default method from the 2006 IPCC Guidelines to estimate $N_2O$ emissions from domestic wastewater. $N_2O$ emissions from domestic wastewater effluent are estimated using *Equation*

*6.7 in the 2006 IPCC Guidelines, Volume 5, Chapter 6.* Specifically, $N_2O$ emissions are assumed to equal the amount of nitrogen discharged to aquatic environments, multiplied by an emission factor.

$$N_2O\ Emissions = N_{EFFLUENT} \bullet EF_{EFFLUENT} \bullet 44/28$$

Where:

$N_2O$ emissions = $N_2O$ emissions in inventory year, kg $N_2O$/yr

$N_{EFFLUENT}$ = nitrogen in the effluent discharged to aquatic environments, kg N/yr

$EF_{EFFLUENT}$ = emission factor for $N_2O$ emissions from discharged to wastewater, kg $N_2O$-N/kg N

The factor 44/28 is the conversion of kg $N_2O$-N into kg $N_2O$.

$N_2O$ emissions from centralized wastewater treatment plants with nitrification and denitrification steps are also taken into account by subtracting the amount of nitrogen associated with $N_2O$ emissions from these plants from the total nitrogen discharged in the wastewater effluent. $N_2O$ emissions from such plants are estimated using *Equation 6.9 in 2006 IPCC, Volume 5, Chapter 6.*

$$N_2O_{PLANTS} = P \bullet T_{PLANT} \bullet F_{IND-COM} \bullet EF_{PLANT}$$

Where:

$N_2O_{PLANTS}$ = total $N_2O$ emissions from plants in inventory year, kg $N_2O$/yr

P = human population

$T_{PLANT}$ = degree of utilization of modern, centralized WWT plants, %

$F_{IND-COM}$ = fraction of industrial and commercial co-discharged protein (default = 1.25),

$EF_{PLANT}$ = emission factor, 3.2 g $N_2O$/person/year

The estimation results are given in Table 7.43. Turkey has developed $T_{PLANT}$ values for each inventory year since 1990 in previous submission. $T_{PLANT}$ values for 1990-2000 period reported as NO because the nitrogen removal process is not available before 2001. After 2001, values are: 8.95, 8.89, 7.94, 7.25, 11.31, 14.84, 15.90, 16.99, 22.71, 27.91, 27.79, 27.68, 29.61, 31.44, 33.82, 36.11, 38.31, 40.22 in %. It has been estimated as; {total amount of wastewater treated from advanced centralised wastewater treatment plants with nitrogen removal processes ($m^3$)/ total amount of wastewater discharged to receiving bodies($m^3$)}*100. $N_2O$ emissions from wastewater between the period 1990-2018, as shown in Figure 7.12., $N_2O$ emissions increase of 322.7% since 1990 till 2018 especially after 2001.

Turkey reports $N_2O$ emissions from industrial wastewater as "IE" in CRF table 5.D. As discussed further below, $N_2O$ emissions from industrial wastewater (category 5.D.2) discharged into sewers is included in the $N_2O$ emissions from domestic wastewater (category 5.D.1).

**Table 7.43 $N_2O$ emissions from wastewater, 1990-2018**

(kt)

| Year | $N_2O$ emissions from wastewater effluent | $N_2O$ emissions from centralized WWT plants | Total $N_2O$ emissions |
|---|---|---|---|
| 1990 | 4.84 | NO | 4.84 |
| 1991 | 4.92 | NO | 4.92 |
| 1992 | 4.97 | NO | 4.97 |
| 1993 | 4.99 | NO | 4.99 |
| 1994 | 5.13 | NO | 5.13 |
| 1995 | 5.24 | NO | 5.24 |
| 1996 | 5.16 | NO | 5.16 |
| 1997 | 5.05 | NO | 5.05 |
| 1998 | 5.31 | NO | 5.31 |
| 1999 | 5.38 | NO | 5.38 |
| 2000 | 5.44 | NO | 5.44 |
| 2001 | 5.39 | 2.33 | 7.72 |
| 2002 | 5.47 | 2.35 | 7.82 |
| 2003 | 5.50 | 2.12 | 7.62 |
| 2004 | 5.58 | 1.96 | 7.54 |
| 2005 | 5.66 | 3.10 | 8.76 |
| 2006 | 5.71 | 4.11 | 9.82 |
| 2007 | 5.76 | 4.46 | 10.22 |
| 2008 | 5.71 | 4.83 | 10.54 |
| 2009 | 5.79 | 6.54 | 12.34 |
| 2010 | 6.04 | 8.17 | 14.20 |
| 2011 | 6.18 | 8.25 | 14.44 |
| 2012 | 6.45 | 8.32 | 14.77 |
| 2013 | 6.57 | 9.02 | 15.59 |
| 2014 | 6.69 | 9.70 | 16.39 |
| 2015 | 6.81 | 10.58 | 17.39 |
| 2016 | 6.94 | 11.45 | 18.39 |
| 2017 | 7.11 | 12.38 | 19.49 |
| 2018 | 7.25 | 13.19 | 20.44 |

**Figure 7.12 $N_2O$ emissions from wastewater, 1990-2018**

**Collection of Activity Data**

The activity data that are needed for estimating $N_2O$ emissions are nitrogen content in the wastewater effluent, country population and average annual per capita protein generation (kg/person/yr).

The total nitrogen in the effluent is estimated using *Equation 6.8 in the 2006 IPCC Guidelines, Volume 5, Chapter 6.*

$$N_{EFFLUENT} = (P \bullet Protein \bullet {}_{NPR} \bullet F_{NON-CON} \bullet F_{IND-COM}) - N_{SLUDGE}$$

Where:

$N_{EFFLUENT}$ = total annual amount of nitrogen in the wastewater effluent, kg N/yr

P = human population

Protein = annual per capita protein consumption, kg/person/yr

$F_{NPR}$ = fraction of nitrogen in protein, kg N/kg protein

$F_{NON-CON}$ = factor for non-consumed protein added to the wastewater

$F_{IND-COM}$ = factor for industrial and commercial co-discharged protein into the sewer system

$N_{SLUDGE}$= nitrogen removed with sludge, kg N/yr

Per capita protein generation consists of intake (consumption) which is available from the FAOSTAT *(http://www.fao.org/faostat/en/#data/FBS/visualize)*. Data can be obtained for Turkey between the years 1990-2013. 2014, 2015, 2016, 2017 and 2018 data were extrapolated due to the lack of data.

Population data is available from the TurkStat *(http://www.turkstat.gov.tr/PreTablo.do?alt_id=1027)* and can be accessed under the *Mid-year Population Statistical Table*. Population and annual per capita protein consumption data are given in Table 7.44.

**Table 7.44 Population and per capita protein consumption, 1990-2018**

| Year | Population (1) (1000's persons) | Per capita protein consumption (2) (kg/person/yr) |
|---|---|---|
| 1990 | 55 120 | 39.88 |
| 1991 | 56 055 | 39.90 |
| 1992 | 56 986 | 39.62 |
| 1993 | 57 913 | 39.16 |
| 1994 | 58 837 | 39.62 |
| 1995 | 59 756 | 39.89 |
| 1996 | 60 671 | 38.64 |
| 1997 | 61 582 | 37.30 |
| 1998 | 62 464 | 38.64 |
| 1999 | 63 364 | 38.57 |
| 2000 | 64 269 | 38.44 |
| 2001 | 65 166 | 37.68 |
| 2002 | 66 003 | 37.75 |
| 2003 | 66 795 | 37.49 |
| 2004 | 67 599 | 37.60 |
| 2005 | 68 435 | 37.70 |
| 2006 | 69 295 | 37.60 |
| 2007 | 70 158 | 37.47 |
| 2008 | 71 052 | 36.69 |
| 2009 | 72 039 | 36.76 |
| 2010 | 73 142 | 37.77 |
| 2011 | 74 224 | 38.13 |
| 2012 | 75 176 | 39.25 |
| 2013 | 76 148 | 39.46 |
| 2014 | 77 182 | 39.68 |
| 2015 | 78 218 | 39.89 |
| 2016 | 79 278 | 40.11 |
| 2017 | 80 811 | 40.33 |
| 2018 | 82 004 | 40.54 |

Source: (1) TurkStat, Mid-year Population Estimations and Projections
(2) FAOSTAT, Food Balance Sheets

Additional relevant parameters to calculate total nitrogen in the effluent are given in Table 7.45. Default values from the*2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.11* are used for the fraction of nitrogen in protein (0.16 kg N/kg protein), the fraction of non-consumed protein (1.4), and the fraction of industrial and commercial co-discharged protein (1.25). As discussed above for domestic wastewater, Turkey assumes that there is zero sludge removed. Regarding the fraction of non-consumed protein, Turkey has applied the value for developed countries using garbage disposals.

**Table 7.45 Parameters for estimation of nitrogen in effluent, 2018**

| Fraction of nitrogen in protein ($F_{NPR}$) (kg N/kg protein) | Fraction of non-consumed protein ($F_{NON-CON}$) | Fraction of industrial and commercial co-discharged protein ($F_{IND-COM}$) | Nitrogen removed with sludge ($N_{SLUDGE}$) (kg) |
|---|---|---|---|
| 0.16 | 1.40 | 1.25 | 0.00 |

**Choice of Emission Factor**

To estimate $N_2O$ emissions from wastewater effluent, the IPCC default $N_2O$ EF ($EF_{EFFLUENT}$) is selected as 0.005 kg $N_2O$-N/kg-N from the *2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.11*.

The IPCC default EF ($EF_{PLANTS}$) to estimate $N_2O$ emissions from centralized wastewater treatment plants of 3.2 g $N_2O$/person/year as given in the 2006 IPCC Guidelines, *Volume 5, Chapter 6, Table 6.11* is applied. To estimate $N_2O$ emissions from such plants, the country-specific values of the degree of utilization of modern, centralized WWT plants ($T_{PLANT}$) are calculated for the whole time series.

### Uncertainties and Time-Series Consistency:

*Domestic Wastewater Treatment and Discharge:* For $CH_4$ emissions, the uncertainty for AD is estimated as 5.0% and for $CH_4$ EF it is calculated as 37.7% by using default uncertainty ranges provided in the *2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.7.*

For $N_2O$ emissions, the uncertainty for AD is estimated as 30.0%. The uncertainty value of the $N_2O$ EF is calculated as 42.4% by using uncertainty values of 30.0% for both $EF_{EFFLUENT}$ and $EF_{PLANTS}$ based on expert judgment since there is no sufficient information in the related section of the 2006 IPCC.

*Industrial Wastewater Treatment and Discharge:* For $CH_4$ emissions, the uncertainty for AD is estimated as 11.2% and for $CH_4$ EF it is calculated as 39.1% by using default uncertainty ranges provided in the *2006 IPCC Guidelines, Volume 5, Chapter 6, Table 6.10.*

The estimates are calculated in a consistent manner over time series.

Monte Carlo analysis has been carried out for the $CH_4$ and $N_2O$ emissions from Wastewater treatment and discharge, for the year 2017. Combined uncertainty in $CH_4$ emissions is was estimated at -40.16% to +40.77% for Domestic wastewater sub-category and-32.71% to 41.28% for Industrial wastewater sub-category while $N_2O$ combined uncertainty range is -24.38% to+25.56%. More detailed information is in Annex 2.

### Source-Specific QA/QC and Verification:

QA/QC procedures implemented for each category in order to verify and improve the inventory under the Turkey's QA/QC plan.

The data used in Wastewater Treatment and Discharge (CRF Category 5.D) are derived from waste statistics database of TurkStat. TurkStat is producing all its statistics according to the European Code of Practice Principles. Therefore, high quality data are used in the emission estimates of this category.

Wherefore Turkey made QC checks in order to provide more accurate data, methane recovery data of some biogas facilities in 2017 are rechecked.

Moreover, QA work was conducted by an external reviewer (expert from CITEPA - Technical Reference Center for Air Pollution and Climate Change - in France) for this category in December 2019.

### Recalculation:

As a result of QC checks, methane recovery data for 2011-2017 are recalculated for just one biogas facility. For instance, this recalculation caused 17 kt $CO_2$ eq. (1.7%) decrease in 2017 $CH_4$ emissions.

For more accurate activity data, the amount of industrial wastewater treated by sectors for 2017 of previous submission has been recalculated by interpolation method due to the availability of 2018 AD.

Total recalculation of $CH_4$ emissions for the entire Wastewater Treatment and Discharge subsector (CRF Category 5.D) resulted in a decrease by 68.7 kt $CO_2$ eq. (2.8%) in 2017. There is no recalculation for Wastewater Treatment and Discharge (CRF Category 5.D) $N_2O$ emissions.

### Planned Improvement:

Turkey is planning to improve the $CH_4$ emission parameters both for the degree of treatment utilization by population class (domestic wastewater) and for the fractional usage for different types of waste treatment and discharge pathways (industrial wastewater) for the whole time series by applying the results achieved from the ongoing study, which is being carried out to determine specific values for those parameters. After the study is completed, the emission and activity data time series will be recalculated accordingly.

### 7.6. Other (Category 5.E)

There are no other activities to be considered under this category.

## 8. OTHER

Turkey does not report any emissions under the category 'Other'.

## 9. INDIRECT CARBON DIOXIDE AND NITROUS OXIDE EMISSIONS

Turkey does not report on indirect carbon dioxide and nitrous oxide emissions.

# 10. RECALCULATIONS AND IMPROVEMENTS

### Recalculations:

Every year the inventory team reviews the latest inventory and tries to determine the conditions that were not meet the TACCC criteria. Based on the outcomes of the examination some AD revisions, reallocation of emissions or error corrections were made in 2018 inventory (2020 submission).

Also the ERT recommendations are one of the most important reasons for recalculations. A centralized review of the 2019 inventory submission of Turkey was organized by the UNFCCC Secretariat from 7 to 12 October 2019. The *Report on the individual review of the inventory submission of Turkey submitted in 2019* has not been finalized yet. However, many recalculations have been made based on the ERT findings in some categories in addition to Turkey's own improvements. All kind of recalculations were described in the Chapters 3-7 in detail, and the reasons for recalculations were also summarized below.

**In energy sector;**

No recalculation in energy sector.

**In IPPU sector;**

In 2.E and 2.F, there is recalculation due to unit error in data entrance.

**In agriculture sector;**

Change of cattle population numbers due to rounding, update in the indirect emission calculations and a revision of the swine manure management systems are the three reasons for the recalculations in the manure management source category. Emission calculations have improved considerably by the latest improvements.

Mainly the addition of default Nbedding values, updating Fsew and Fcomp calculations by adding N % contents to the calculations, rounding of cattle population numbers, the use of country-specific MMS distribution for swine, revision/update in crop residues activity data (only for the year 2017) are the reasons for the increase in agricultural soils category. Moreover, the changes in direct emissions from the agricultural soils category have implications on the emissions from the indirect sources of the same category as well.

**In LULUCF sector;**

Forest Land: There is no recalculation for Forest Land category in this submission.

Grassland: The WL-GL and OL-GL subcategories have been recalculated for the entire reporting period. Since the calculation results were not entered as kt in 2017, the results for this year were recalculated as kt in all time series.

Wetlands: The peat extraction remaining peat extraction subcategories have been recalculated for the entire reporting period. Since the calculation results were not entered as kt in 2017, the results for this year were recalculated as kt in all time series.

HWP: There is no recalculation for HWP category in this submission.

Other Gases: There is no recalculation for other gases in this submission.

**In waste sector;**

A comprehensive research was conducted for the activity data of Biological Treatment of Solid Waste (Category 5.B). Thus, entire time series between 1990-2017 is recalculated according to the background information of AD which is explained in detail under the title of 'Collection of Activity Data' in the relevant category.

In Solid Waste Disposal (Category 5.A), MSW disposed in managed SWDS has been recalculated for year 2017 by linear interpolation in the 2020 inventory submission due to the availability of 2018 survey data. This affected the amount of MSW disposed in unmanaged SWDS for 2017 too. Also, 2017 waste generation rate of previous submission is recalculated by interpolation method due to the availability of 2018 IW data. Another reason for the recalculation is the revision of the 2017 GDP data. 2017 % to SWDS data of previous submission is also recalculated by interpolation method due to the availability of 2018 IW generated data. Moreover, methane recovery data from some landfill gas recovery facilities are updated after the year 2016 as a result of verification activities.

Similarly, 2017 data for the fraction of MSW open-burned has been recalculated by linear interpolation due to the availability of 2018 survey data from TurkStat's Municipal Waste Statistics Survey in Category 5.C.

For Category 5.D, the amount of industrial wastewater treated by sectors for 2017 of previous submission has been recalculated by interpolation method due to the availability of 2018 AD. Also, methane recovery data for 2011-2017 are recalculated.

The reasons and the implications of recalculations by CRF category are given in the below table for 1990 and 2017.

**Table 10.1 Recalculations made in 2018 inventory and implications to the emission level, 1990 and 2017**

| CRF category | Reasons for recalculation | Implication to the CRF category level (kt $CO_2$ eq.) | | Implication to the total emission w/o LULUCF (%) | |
|---|---|---|---|---|---|
| | | 1990 | 2017 | 1990 | 2017 |
| **Total (net emissions)** | | **154** | **-2 475** | **0.07** | **-0.47** |
| **2. Industrial Processes** | | **0.00** | **-2 844** | **0.00** | **-0.54** |
| E. Electronic industry | Correction of unit error | NO | 45 | NO | 0.01 |
| F. Product uses as ODS substitutes | Correction of unit error | NO | -2 889 | NO | -0.55 |
| **3. Agriculture** | | **169** | **303** | **0.08** | **0.06** |
| A. Enteric fermentation | Rounding of cattle population number | 0.00 | 0.00 | 0.00 | 0.00 |
| B. Manure management | Revision of swine MMS distribution, update in indirect emissions calculation | 67 | 104 | 0.03 | 0.02 |
| D. Agricultural soils | Mainly the addition of default Nbedding values, addition of N content % values to the calculation (for Fsew and Fcomp), rounding of cattle numbers and MMS change for swine, revision/update in crop residues activity data (only for year 2017). | 102 | 199 | 0.05 | 0.04 |

**Table 10.1 Recalculations made in 2018 inventory and implications to the emission level, 1990 and 2017 (cont'd)**

| CRF category | Reasons for recalculation | Implication to the CRF category level (kt $CO_2$ eq.) | | Implication to the total emission w/o LULUCF (%) | |
|---|---|---|---|---|---|
| | | 1990 | 2017 | 1990 | 2017 |
| **4. Land use, land-use change and forestry** | | **-12** | **25** | **-0.01** | **0.00** |
| C. Grassland | Since the calculation results were not entered as kt in 2017, the results for this year were recalculated as kt in all time series. | 0.00 | 65 | 0.00 | 0.01 |
| D. Wetlands | Since the calculation results were not entered as kt in 2017, the results for this year were recalculated as kt in all time series. | -12 | -40 | -0.01 | -0.01 |
| **5. Waste** | | **-3** | **41** | **0.00** | **0.01** |
| A. Solid waste disposal | Revisions of the amount of MSW disposed in SWDS, waste generation rate, GDP data, % to SWDS data and methane recovery data for 2017. | 0.00 | -36 | 0.00 | -0.01 |
| B. Biological treatment of solid waste | Revision of AD for entire time series between 1990-2017. | -3 | 9 | 0.00 | 0.00 |
| C. Incineration and open burning of waste | Updating the fraction of MSW open-burned for 2017. | 0.00 | -1 | 0.00 | 0.00 |
| D. Wastewater treatment and discharge | Revisions of the amount of industrial wastewater treated by sectors and methane recovery data. | 0.00 | 69 | 0.00 | 0.01 |
| **Total $CO_2$ equivalent emissions without land use, land-use change and forestry** | | **166** | **-2 500** | **0.08** | **-0.48** |
| **Total $CO_2$ equivalent emissions with land use, land-use change and forestry** | | **154** | **-2 475** | **0.07** | **-0.47** |

Figures in the table may not add up to the totals due to rounding.

### Planned Improvements:

Considerable improvements have been made in the 2018 inventory (2020 submission). However, there are still areas to be improved mainly related to using higher tiers, especially for key categories. Planned improvements are summarized as follows:

**In energy sector;**

Prior to 2011 several manufacturing sectors that have their own categories (Pulp, Paper & Print; Non-metallic minerals; Food processing, beverages & tobacco) were not fully separated out in the national energy balance and therefore some or all of the emissions from these categories were reported under section 1A2g. This is because in the calculation of 1A2 subcategories the national energy balance tables are used and national energy balance tables are not created as time series. All relevant institutions are working together in order to overcome this inconsistency problem.

Prior to 2015 1A4a and 1A4b categories were not separated out in the national energy balance and therefore all of the emissions from these categories were reported under section 1A4b. However, since 2015 they are separated. All relevant institutions are working together in order to overcome this inconsistency problem and allocate 1A4a and 1A4b categories in time series.

MENR worked on agricultural association for modeling the agricultural diesel oil consumption and the disaggregation of diesel oil consumption was achieved in 2015 national energy balance tables. However national energy balance tables are not in time series therefore the allocation problem still exists between 2012 and 2014. All relevant institutions are working together and make planning in order to overcome this inconsistency problem.

Since the 1.B.1 category is a key category in terms of emission trend of $CH_4$, the tiers in $CH_4$ estimation needs to be increased. Detailed investigation has been performed to find out the availability of country specific or basin specific EFs within both general directorates for lignite and hard coal structured under the MENR, namely, DG Turkish Lignite Enterprises and DG Turkish Hard Coal Enterprises. However, information for the generation of country-specific EFs are not available centrally in those coal authorities. Therefore, it is necessary to communicate and cooperate with mining enterprises directly to search the availability of required information for T2 estimation of $CH_4$.

For 1.B.2 In order to increase the tiers for $CH_4$ emission estimation, availability of detailed information have been searched. It is planned to continue the investigation to find out the availability or possibility of availability of appropriate data for higher tiers.

**In IPPU sector;**

In cement production, Turkey recently made improvements in the representativeness of the country specific carbonate content of the clinker. It is planned to collect data on plant specific CKD for the next submissions.

For lime production; it is planned to obtain a country specific emission factor for dolomitic lime.

For Product Use as Substitutes for ODS, improvements in the sector data will be done within the scope of "*Technical Assistance for Increased Capacity for Transposition and Capacity Building on F-Gases*" project which has started in June 2017 and will last in May 2020.

For Other Product Manufacture and Use (2.G) improvements in the sector data will be done within the scope of "*Technical Assistance for Increased Capacity for Transposition and Capacity Building on F-Gases*"project which has started in June 2017 and will last in May 2020.

**In agriculture sector;**

It is planned to use Tier 2 method for estimating enteric fermentation emissions of another important animal category (sheep) in the next submissions.

Turkey searches also for country specific parameters related to using Tier 2 method in manure management.

**In LULUCF sector;**

In Forestland category the increment data is planned to be disaggregated for ecozones in the medium term. The soil and dead organic matter carbon stocks will be updated as more national studies are available.

In Cropland category perennial crops is planned to be disaggregated for major species including olives, vineyards etc. if a method that can be embedded into the current system can be developed. Related to management of annual croplands there are area data available but has not been estimated in this submission. The removals/emissions from cropland management including reduced tillage is planned to be reported not in the short term but in medium or long term.

In Grassland category it will be possible to estimate CSC in soils when range rehabilitation data is available. There are several studies going on in grasslands in the country. The results will be incorporated into estimates as they become available.

Turkey is a partner of ICP Forests program. The ICP forest project's soil analysis in Turkey was initiated in January 2015 and planned to be finished by 2019. But it is not completed yet. The results of this project may enable us to improve soil and litter carbon stocks.

The EU funded project entitled "The Technical Assistance for Developed an Analytical Basis for the LULUCF Sector Project" has been started in 2017 and finish in July in 2019. The project provided a spatially explicit land use tracking system. In this regard it is planned to implement a new project in the long term.

**In waste sector;**

In the scope of TurkStat's Waste Disposal and Recovery Facilities Survey, it will be determined whether there is any flaring on waste disposal sites (CRF Category 5.A). Based on the gathered information, flaring would be included in next submission.

Emissions and amount of methane for energy recovery from anaerobic digestion at biogas facilities (CRF Category 5.B.2) will be included in next inventory submissions depending on the availability of such treatment processes.

In Wastewater Treatment and Discharge (CRF Category 5.D), Turkey is planning to improve the $CH_4$ emission parameters both for the degree of treatment utilization by population class (domestic wastewater) and for the fractional usage for different types of waste treatment and discharge pathways (industrial wastewater) for the whole time series by applying the results achieved from the ongoing study, which is being carried out to determine specific values for those parameters. After the study is completed, the emission and activity data time series will be recalculated accordingly.

# Annex 1: Key Categories

This annex presents the use of an IPCC T1 key category analysis and results for Turkish's inventory submission. The 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) recommend as good practice the identification of key categories of emissions and removals. The intent is to help inventory agencies prioritize their efforts to improve overall estimates. A key category is defined as "one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of green-house gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions and removals" (2006 IPCC Guidelines); this term is used in reference to both source and sink categories.

The IPCC T1 quantitative approach is used to identify key categories from two perspectives: their contribution to the overall emissions and their contribution to the emission trend. The level assessment analyzes the emission contribution that each category makes to the national total (with and without LULUCF). The trend assessment uses each category's relative contribution to the over-all emissions, but assigns greater weight to the categories whose relative trend departs from the overall trend (with and without LULUCF). In this assessment, trends are calculated as the absolute changes between the base and most recent inventory years.

The percent contributions to both levels and trends in emissions are calculated and sorted from greatest to least. A cumulative total is calculated for both approaches. A cumulative contribution threshold of 95% for both level and trend assessments is a reasonable approximation of 90% uncertainty for the T1 method of determining key categories (2006 IPCC Guidelines). This threshold has therefore been used in this analysis to define an upper boundary for key category identification. Hence, when source and sink contributions are sorted in decreasing order of importance, those largest ones that together contribute to 95% of the cumulative total are considered quantitatively to be key category.

Level contribution each source or sink is calculated according to Equation 4.1. in 2006 IPCC Guidelines while trend assessment is calculated according to the Equation 4.2. and 4.3.

In 2018 inventory key source analysis, there were 30 key source categories shown in Table A1 below.

**Table A1 Key category analysis summary, 2018**

| KEY CATEGORIES OF EMISSIONS AND REMOVALS | Gas | Criteria used for key source identification | | Key category excluding LULUCF | Key category including LULUCF |
|---|---|---|---|---|---|
| | | L | T | | |
| 1.A.1 Fuel combustion - Energy Industries - Liquid Fuels | CO2 | X | X | X | X |
| 1.A.1 Fuel combustion - Energy Industries - Solid Fuels | CO2 | X | X | X | X |
| 1.A.1 Fuel combustion - Energy Industries - Gaseous Fuels | CO2 | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels | CO2 | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Solid Fuels | CO2 | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels | CO2 | X | X | X | X |
| 1.A.2 Fuel combustion - Manufacturing Industries and Construction - Other Fossil | CO2 | | X | X | X |
| 1.A.3.a Domestic Aviation | CO2 | X | X | X | X |
| 1.A.3.b Road Transportation | CO2 | X | X | X | X |
| 1.A.4 Other Sectors - Liquid Fuels | CO2 | X | X | X | X |
| 1.A.4 Other Sectors - Solid Fuels | CO2 | X | X | X | X |
| 1.A.4 Other Sectors - Gaseous Fuels | CO2 | X | X | X | X |
| 1.A.4 Other Sectors - Biomass | CH4 | | X | X | X |
| 1.B.1 Fugitive emissions from Solid Fuels | CH4 | X | X | X | X |
| 1.B.2.b Natural Gas | CH4 | | X | X | X |
| 2.A.1 Cement Production | CO2 | X | X | X | X |
| 2.A.2 Lime Production | CO2 | X | X | X | X |
| 2.A.4 Other Process Uses of Carbonates | CO2 | X | X | X | X |
| 2.C.1 Iron and Steel Production | CO2 | X | | X | X |
| 2.F.6 Other Applications | Aggregate F-gases | X | X | X | X |
| 3.A Enteric Fermentation | CH4 | X | X | X | X |
| 3.B Manure Management | CH4 | X | | X | X |
| 3.B Manure Management | N2O | X | X | X | X |
| 3.D.1 Direct N2O Emissions From Managed Soils | N2O | X | X | X | X |
| 3.D.2 Indirect N2O Emissions From Managed Soils | N2O | | X | X | X |
| 4.A.1 Forest Land Remaining Forest Land | CO2 | X | X | | X |
| 4.G Harvested Wood Products | CO2 | X | X | | X |
| 5.A Solid Waste Disposal | CH4 | X | X | X | X |
| 5.D Wastewater Treatment and Discharge | CH4 | X | X | X | X |
| 5.D Wastewater Treatment and Discharge | N2O | X | X | X | X |

**Table A2 Key category analysis level assessment with LULUCF, 2018**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 1.A.1. | Energy industries | Solid fuels | CO2 | 113 522 | 113 522 | 18.29 | 18.29 |
| 4.A.1. | Forest Land Remaining Forest Land | | CO2 | -84 537 | 84 537 | 13.62 | 31.91 |
| 1.A.3.b. | Road Transportation | | CO2 | 77 289 | 77 289 | 12.45 | 44.37 |
| 1.A.1. | Energy industries | Gaseous fuels | CO2 | 38 794 | 38 794 | 6.25 | 50.62 |
| 2.A.1. | Cement Production (Mineral Products) | | CO2 | 37 026 | 37 026 | 5.97 | 56.58 |
| 1.A.4. | Other sectors | Gaseous fuels | CO2 | 32 135 | 32 135 | 5.18 | 61.76 |
| 3.A. | Enteric fermentation | | CH4 | 32 060 | 32 060 | 5.17 | 66.93 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CO2 | 21 832 | 21 832 | 3.52 | 70.44 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CO2 | 20 748 | 20 748 | 3.34 | 73.79 |
| 3.D.a. | Direct N2O emissions from managed soils | | N2O | 20 135 | 20 135 | 3.24 | 77.03 |
| 1.A.4. | Other sectors | Solid fuels | CO2 | 16 161 | 16 161 | 2.60 | 79.63 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CO2 | 14 889 | 14 889 | 2.40 | 82.03 |
| 2.C.1. | Iron and Steel Production | | CO2 | 12 537 | 12 537 | 2.02 | 84.05 |
| 4.G. | Harvested Wood Products | | CO2 | -12 135 | 12 135 | 1.96 | 86.01 |
| 1.A.4. | Other sectors | Liquid fuels | CO2 | 11 806 | 11 806 | 1.90 | 87.91 |
| 5.A. | Solid waste disposal | | CH4 | 8 864 | 8 864 | 1.43 | 89.34 |
| 5.D. | Wastewater treatment and discharge | | N2O | 6 091 | 6 091 | 0.98 | 90.32 |
| 1.B.1 | Solid fuels | | CH4 | 4 885 | 4 885 | 0.79 | 91.11 |
| 2.F.6. | Other applications | | HFC | 4 866 | 4 866 | 0.78 | 91.89 |
| 1.A.1. | Energy industries | Liquid fuels | CO2 | 4 759 | 4 759 | 0.77 | 92.66 |
| 3.B. | Manure management | | N2O | 4 557 | 4 557 | 0.73 | 93.39 |
| 3.B. | Manure management | | CH4 | 3 886 | 3 886 | 0.63 | 94.02 |
| 1.A.3.a. | Domestic Aviation | | CO2 | 3 648 | 3 648 | 0.59 | 94.61 |
| 2.A.4. | Other process uses of carbonates | | CO2 | 3 356 | 3 356 | 0.54 | 95.15 |
| 2.A.2. | Lime Production (Mineral Products) | | CO2 | 2 787 | 2 787 | 0.45 | 95.60 |
| 5.D. | Wastewater treatment and discharge | | CH4 | 2 786 | 2 786 | 0.45 | 96.05 |
| 3.D.b. | Indirect N2O Emissions from managed soils | | N2O | 2 562 | 2 562 | 0.41 | 96.46 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CO2 | 1 843 | 1 843 | 0.30 | 96.76 |
| 1.B.2.b | Natural Gas | | CH4 | 1 826 | 1 826 | 0.29 | 97.05 |

**Table A2 Key category analysis level assessment with LULUCF, 2018 (cont'd)**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 2.B.2. | Nitric acid production | | N2O | 1 823 | 1 823 | 0.29 | 97.34 |
| 3.H. | Urea application | | CO2 | 1 257 | 1 257 | 0.20 | 97.55 |
| 1.A.3.b. | Road Transportation | | N2O | 1 227 | 1 227 | 0.20 | 97.74 |
| 1.A.4. | Other sectors | Liquid fuels | N2O | 1 066 | 1 066 | 0.17 | 97.92 |
| 2.B.1. | Ammonia Production | | CO2 | 1 038 | 1 038 | 0.17 | 98.08 |
| 1.A.4. | Other sectors | Solid fuels | CH4 | 952.6 | 952.6 | 0.15 | 98.24 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CO2 | 814.3 | 814.3 | 0.13 | 98.37 |
| 4.C.2. | Land Converted to Grassland | | CO2 | 698.8 | 698.8 | 0.11 | 98.48 |
| 4.F.2. | Land Converted to Other Land | | CO2 | 650.1 | 650.1 | 0.10 | 98.58 |
| 2.A.3. | Glass Production | | CO2 | 650.0 | 650.0 | 0.10 | 98.69 |
| 1.A.3.e. | Other transportation | | CO2 | 541.4 | 541.4 | 0.09 | 98.78 |
| 1.A.1. | Energy industries | Gaseous fuels | N2O | 536.5 | 536.5 | 0.09 | 98.86 |
| 1.A.4. | Other sectors | Biomass | CH4 | 488.4 | 488.4 | 0.08 | 98.94 |
| 4.B.2. | Land Converted to Cropland | | CO2 | 451.4 | 451.4 | 0.07 | 99.01 |
| 1.A.1. | Energy industries | Solid fuels | N2O | 444.8 | 444.8 | 0.07 | 99.09 |
| 1.B.2.c | Venting and flaring | | CH4 | 443.9 | 443.9 | 0.07 | 99.16 |
| 4.E.2. | Land Converted to Settlements | | CO2 | 406.9 | 406.9 | 0.07 | 99.22 |
| 1.A.3.b. | Road Transportation | | CH4 | 391.6 | 391.6 | 0.06 | 99.29 |
| 1.A.3.c. | Railways | | CO2 | 388.3 | 388.3 | 0.06 | 99.35 |
| 1.A.1. | Energy industries | Other fossil fuels | CO2 | 368.6 | 368.6 | 0.06 | 99.41 |
| 4.A.2. | Land Converted to Forest Land | | CO2 | -340.2 | 340.2 | 0.05 | 99.46 |
| 1.B.2.a | Oil | | CH4 | 331.8 | 331.8 | 0.05 | 99.52 |
| 3.C. | Rice cultivation | | CH4 | 252.4 | 252.4 | 0.04 | 99.56 |
| 2.B.7. | Soda ash production | | CO2 | 224.4 | 224.4 | 0.04 | 99.59 |
| 4.D.2. | Land Converted to Wetlands | | CO2 | 218.2 | 218.2 | 0.04 | 99.63 |
| 2.F.3. | Fire protection | | HFC | 215.4 | 215.4 | 0.03 | 99.66 |
| 2.D.1. | Lubricant Use | | CO2 | 193.4 | 193.4 | 0.03 | 99.69 |
| 2.C.2. | Ferroalloys Production | | CO2 | 169.8 | 169.8 | 0.03 | 99.72 |
| 1.B.2.c | Venting and flaring | | CO2 | 167.9 | 167.9 | 0.03 | 99.75 |
| 3.F. | Field burning of agricultural residues | | CH4 | 124.3 | 124.3 | 0.02 | 99.77 |
| 4.B.1. | Cropland Remaining Cropland | | CO2 | -116.8 | 116.8 | 0.02 | 99.79 |

**Table A2 Key category analysis level assessment with LULUCF, 2018 (cont'd)**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 2.C.3. | Aluminium Production | | CO2 | 107.3 | 107.3 | 0.02 | 99.81 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CO2 | 106.5 | 106.5 | 0.02 | 99.82 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | N2O | 87.7 | 87.7 | 0.01 | 99.84 |
| 1.A.4. | Other sectors | Biomass | N2O | 77.6 | 77.6 | 0.01 | 99.85 |
| 1.A.4. | Other sectors | Solid fuels | N2O | 72.9 | 72.9 | 0.01 | 99.86 |
| 1.A.4. | Other sectors | Gaseous fuels | CH4 | 72.7 | 72.7 | 0.01 | 99.87 |
| 2.G.1. | Electrical equipment | | SF6 | 71.4 | 71.4 | 0.01 | 99.88 |
| 4.(IV).2. | Indirect N2O Emissions from nitrogen leaching and run-off | | N2O | 70.5 | 70.5 | 0.01 | 99.90 |
| 2.E.5. | Other | | SF6 | 57.0 | 57.0 | 0.01 | 99.90 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CH4 | 49.2 | 49.2 | 0.01 | 99.91 |
| 1.A.3.c. | Railways | | N2O | 45.8 | 45.8 | 0.01 | 99.92 |
| 1.A.2. | Manufacturing industries and construction | Biomass | N2O | 41.6 | 41.6 | 0.01 | 99.93 |
| 3.F. | Field burning of agricultural residues | | N2O | 38.4 | 38.4 | 0.01 | 99.93 |
| 1.A.3.a. | Domestic Aviation | | N2O | 37.8 | 37.8 | 0.01 | 99.94 |
| 2.C.3. | Aluminium Production | | PFC | 36.6 | 36.6 | 0.01 | 99.94 |
| 1.A.2. | Manufacturing industries and construction | Biomass | CH4 | 26.2 | 26.2 | 0.00 | 99.95 |
| 1.A.1. | Energy industries | Gaseous fuels | CH4 | 24.6 | 24.6 | 0.00 | 99.95 |
| 4.B.2. | Land Converted to Cropland | | N2O | 22.7 | 22.7 | 0.00 | 99.96 |
| 1.A.1. | Energy industries | Solid fuels | CH4 | 19.9 | 19.9 | 0.00 | 99.96 |
| 1.A.4. | Other sectors | Liquid fuels | CH4 | 19.2 | 19.2 | 0.00 | 99.96 |
| 1.A.4. | Other sectors | Gaseous fuels | N2O | 17.3 | 17.3 | 0.00 | 99.97 |
| 2.C.1. | Iron and Steel Production | | CH4 | 17.1 | 17.1 | 0.00 | 99.97 |
| 4.A.1. | Forest Land Remaining Forest Land | | CH4 | 16.6 | 16.6 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | N2O | 15.8 | 15.8 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CH4 | 13.1 | 13.1 | 0.00 | 99.98 |
| 2.D.2. | Paraffin Wax Use | | CO2 | 13.0 | 13.0 | 0.00 | 99.98 |
| 5.B. | Biological treatment of solid waste | | CH4 | 11.9 | 11.9 | 0.00 | 99.98 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | N2O | 11.8 | 11.8 | 0.00 | 99.98 |
| 4.A.1. | Forest Land Remaining Forest Land | | N2O | 11.0 | 11.0 | 0.00 | 99.98 |
| 1.A.1. | Energy industries | Biomass | N2O | 10.2 | 10.2 | 0.00 | 99.99 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CH4 | 10.0 | 10.0 | 0.00 | 99.99 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CH4 | 9.9 | 9.9 | 0.00 | 99.99 |

**Table A2 Key category analysis level assessment with LULUCF, 2018 (cont'd)**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 4.C.2. | Land Converted to Grassland | | N2O | 8.7 | 8.7 | 0.00 | 99.99 |
| 5.B. | Biological treatment of solid waste | | N2O | 8.5 | 8.5 | 0.00 | 99.99 |
| 2.C.5. | Lead Production | | CO2 | 8.1 | 8.1 | 0.00 | 99.99 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | N2O | 6.7 | 6.7 | 0.00 | 99.99 |
| 2.B.5. | Carbide production | | CO2 | 6.2 | 6.2 | 0.00 | 99.99 |
| 1.B.2.a | Oil | | CO2 | 4.1 | 4.1 | 0.00 | 100.00 |
| 4.D.2. | Land Converted to Wetlands | | N2O | 4.0 | 4.0 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Liquid fuels | N2O | 3.3 | 3.3 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Other fossil fuels | N2O | 3.1 | 3.1 | 0.00 | 100.00 |
| 1.B.2.b | Natural Gas | | CO2 | 2.5 | 2.5 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CH4 | 2.0 | 2.0 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Other fossil fuels | CH4 | 1.9 | 1.9 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Liquid fuels | CH4 | 1.9 | 1.9 | 0.00 | 100.00 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | N2O | 1.8 | 1.8 | 0.00 | 100.00 |
| 1.A.3.a. | Domestic Aviation | | CH4 | 1.7 | 1.7 | 0.00 | 100.00 |
| 5.C. | Incineration and open burning of waste | | CO2 | 1.2 | 1.2 | 0.00 | 100.00 |
| 2.B.8. | Petrochemical and carbon black production | | CO2 | 1.2 | 1.2 | 0.00 | 100.00 |
| 5.C. | Incineration and open burning of waste | | CH4 | 1.0 | 1.0 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Biomass | CH4 | 1.0 | 1.0 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | N2O | 0.8 | 0.8 | 0.00 | 100.00 |
| 1.B.2.c | Venting and flaring | | N2O | 0.7 | 0.7 | 0.00 | 100.00 |
| 1.A.3.c. | Railways | | CH4 | 0.6 | 0.6 | 0.00 | 100.00 |
| 4.A.2. | Land Converted to Forest Land | | CH4 | 0.4 | 0.4 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | N2O | 0.3 | 0.3 | 0.00 | 100.00 |
| 4.A.2. | Land Converted to Forest Land | | N2O | 0.3 | 0.3 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | CH4 | 0.2 | 0.2 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CH4 | 0.2 | 0.2 | 0.00 | 100.00 |
| 5.C. | Incineration and open burning of waste | | N2O | 0.2 | 0.2 | 0.00 | 100.00 |
| 1.C. | CO2 Transport and storage | | CO2 | 0.1 | 0.1 | 0.00 | 100.00 |
| 2.E.5. | Other | | HFC | 0.1 | 0.1 | 0.00 | 100.00 |
| 4.D.1.1. | Peat Extraction Remaining Peat Extraction | | CO2 | 0.0 | 0.0 | 0.00 | 100.00 |
| 4.C.1. | Grassland Remaining Grassland | | CO2 | 0.0 | 0.0 | 0.00 | 100.00 |
| **Total** | | | | **426 371.90** | **620 630.52** | | |

**Table A3 Key category analysis level assessment without LULUCF, 2018**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 1.A.1. | Energy industries | Solid fuels | CO2 | 113 522 | 113 522 | 21.79 | 21.79 |
| 1.A.3.b. | Road Transportation | | CO2 | 77 289 | 77 289 | 14.84 | 36.63 |
| 1.A.1. | Energy industries | Gaseous fuels | CO2 | 38 794 | 38 794 | 7.45 | 44.08 |
| 2.A.1. | Cement Production (Mineral Products) | | CO2 | 37 026 | 37 026 | 7.11 | 51.18 |
| 1.A.4. | Other sectors | Gaseous fuels | CO2 | 32 135 | 32 135 | 6.17 | 57.35 |
| 3.A. | Enteric fermentation | | CH4 | 32 060 | 32 060 | 6.15 | 63.51 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CO2 | 21 832 | 21 832 | 4.19 | 67.70 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CO2 | 20 748 | 20 748 | 3.98 | 71.68 |
| 3.D.a. | Direct N2O emissions from managed soils | | N2O | 20 135 | 20 135 | 3.87 | 75.54 |
| 1.A.4. | Other sectors | Solid fuels | CO2 | 16 161 | 16 161 | 3.10 | 78.65 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CO2 | 14 889 | 14 889 | 2.86 | 81.50 |
| 2.C.1. | Iron and Steel Production | | CO2 | 12 537 | 12 537 | 2.41 | 83.91 |
| 1.A.4. | Other sectors | Liquid fuels | CO2 | 11 806 | 11 806 | 2.27 | 86.18 |
| 5.A. | Solid waste disposal | | CH4 | 8 864 | 8 864 | 1.70 | 87.88 |
| 5.D. | Wastewater treatment and discharge | | N2O | 6 091 | 6 091 | 1.17 | 89.05 |
| 1.B.1 | Solid fuels | | CH4 | 4 885 | 4 885 | 0.94 | 89.99 |
| 2.F.6. | Other applications | | HFC | 4 866 | 4 866 | 0.93 | 90.92 |
| 1.A.1. | Energy industries | Liquid fuels | CO2 | 4 759 | 4 759 | 0.91 | 91.83 |
| 3.B. | Manure management | | N2O | 4 557 | 4 557 | 0.87 | 92.71 |
| 3.B. | Manure management | | CH4 | 3 886 | 3 886 | 0.75 | 93.45 |
| 1.A.3.a. | Domestic Aviation | | CO2 | 3 648 | 3 648 | 0.70 | 94.15 |
| 2.A.4. | Other process uses of carbonates | | CO2 | 3 356 | 3 356 | 0.64 | 94.80 |
| 2.A.2. | Lime Production (Mineral Products) | | CO2 | 2 787 | 2 787 | 0.53 | 95.33 |
| 5.D. | Wastewater treatment and discharge | | CH4 | 2 786 | 2 786 | 0.53 | 95.87 |
| 3.D.b. | Indirect N2O Emissions from managed soils | | N2O | 2 562 | 2 562 | 0.49 | 96.36 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CO2 | 1 843 | 1 843 | 0.35 | 96.71 |
| 1.B.2.b | Natural Gas | | CH4 | 1 826 | 1 826 | 0.35 | 97.06 |
| 2.B.2. | Nitric acid production | | N2O | 1 823 | 1 823 | 0.35 | 97.41 |
| 3.H. | Urea application | | CO2 | 1 257 | 1 257 | 0.24 | 97.66 |
| 1.A.3.b. | Road Transportation | | N2O | 1 227 | 1 227 | 0.24 | 97.89 |

**Table A3 Key category analysis level assessment without LULUCF, 2018 (cont'd)**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 1.A.4. | Other sectors | Liquid fuels | N2O | 1 066 | 1 066 | 0.20 | 98.10 |
| 2.B.1. | Ammonia Production | | CO2 | 1 038 | 1 038 | 0.20 | 98.30 |
| 1.A.4. | Other sectors | Solid fuels | CH4 | 952.6 | 952.6 | 0.18 | 98.48 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CO2 | 814.3 | 814.3 | 0.16 | 98.63 |
| 2.A.3. | Glass Production | | CO2 | 650.0 | 650.0 | 0.12 | 98.76 |
| 1.A.3.e. | Other transportation | | CO2 | 541.4 | 541.4 | 0.10 | 98.86 |
| 1.A.1. | Energy industries | Gaseous fuels | N2O | 536.5 | 536.5 | 0.10 | 98.97 |
| 1.A.4. | Other sectors | Biomass | CH4 | 488.4 | 488.4 | 0.09 | 99.06 |
| 1.A.1. | Energy industries | Solid fuels | N2O | 444.8 | 444.8 | 0.09 | 99.15 |
| 1.B.2.c | Venting and flaring | | CH4 | 443.9 | 443.9 | 0.09 | 99.23 |
| 1.A.3.b. | Road Transportation | | CH4 | 391.6 | 391.6 | 0.08 | 99.31 |
| 1.A.3.c. | Railways | | CO2 | 388.3 | 388.3 | 0.07 | 99.38 |
| 1.A.1. | Energy industries | Other fossil fuels | CO2 | 368.6 | 368.6 | 0.07 | 99.45 |
| 1.B.2.a | Oil | | CH4 | 331.8 | 331.8 | 0.06 | 99.51 |
| 3.C. | Rice cultivation | | CH4 | 252.4 | 252.4 | 0.05 | 99.56 |
| 2.B.7. | Soda ash production | | CO2 | 224.4 | 224.4 | 0.04 | 99.61 |
| 2.F.3. | Fire protection | | HFC | 215.4 | 215.4 | 0.04 | 99.65 |
| 2.D.1. | Lubricant Use | | CO2 | 193.4 | 193.4 | 0.04 | 99.68 |
| 2.C.2. | Ferroalloys Production | | CO2 | 169.8 | 169.8 | 0.03 | 99.72 |
| 1.B.2.c | Venting and flaring | | CO2 | 167.9 | 167.9 | 0.03 | 99.75 |
| 3.F. | Field burning of agricultural residues | | CH4 | 124.3 | 124.3 | 0.02 | 99.77 |
| 2.C.3. | Aluminium Production | | CO2 | 107.3 | 107.3 | 0.02 | 99.79 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CO2 | 106.5 | 106.5 | 0.02 | 99.81 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | N2O | 87.7 | 87.7 | 0.02 | 99.83 |
| 1.A.4. | Other sectors | Biomass | N2O | 77.6 | 77.6 | 0.01 | 99.85 |
| 1.A.4. | Other sectors | Solid fuels | N2O | 72.9 | 72.9 | 0.01 | 99.86 |
| 1.A.4. | Other sectors | Gaseous fuels | CH4 | 72.7 | 72.7 | 0.01 | 99.87 |
| 2.G.1. | Electrical equipment | | SF6 | 71.4 | 71.4 | 0.01 | 99.89 |
| 2.E.5. | Other | | SF6 | 57.0 | 57.0 | 0.01 | 99.90 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CH4 | 49.2 | 49.2 | 0.01 | 99.91 |

**Table A3 Key category analysis level assessment without LULUCF, 2018 (cont'd)**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 1.A.3.c. | Railways | | N2O | 45.8 | 45.8 | 0.01 | 99.92 |
| 1.A.2. | Manufacturing industries and construction | Biomass | N2O | 41.6 | 41.6 | 0.01 | 99.92 |
| 3.F. | Field burning of agricultural residues | | N2O | 38.4 | 38.4 | 0.01 | 99.93 |
| 1.A.3.a. | Domestic Aviation | | N2O | 37.8 | 37.8 | 0.01 | 99.94 |
| 2.C.3. | Aluminium Production | | PFC | 36.6 | 36.6 | 0.01 | 99.95 |
| 1.A.2. | Manufacturing industries and construction | Biomass | CH4 | 26.2 | 26.2 | 0.01 | 99.95 |
| 1.A.1. | Energy industries | Gaseous fuels | CH4 | 24.6 | 24.6 | 0.00 | 99.96 |
| 1.A.1. | Energy industries | Solid fuels | CH4 | 19.9 | 19.9 | 0.00 | 99.96 |
| 1.A.4. | Other sectors | Liquid fuels | CH4 | 19.2 | 19.2 | 0.00 | 99.96 |
| 1.A.4. | Other sectors | Gaseous fuels | N2O | 17.3 | 17.3 | 0.00 | 99.97 |
| 2.C.1. | Iron and Steel Production | | CH4 | 17.1 | 17.1 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | N2O | 15.8 | 15.8 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CH4 | 13.1 | 13.1 | 0.00 | 99.98 |
| 2.D.2. | Paraffin Wax Use | | CO2 | 13.0 | 13.0 | 0.00 | 99.98 |
| 5.B. | Biological treatment of solid waste | | CH4 | 11.9 | 11.9 | 0.00 | 99.98 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | N2O | 11.8 | 11.8 | 0.00 | 99.98 |
| 1.A.1. | Energy industries | Biomass | N2O | 10.2 | 10.2 | 0.00 | 99.98 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CH4 | 10.0 | 10.0 | 0.00 | 99.99 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CH4 | 9.9 | 9.9 | 0.00 | 99.99 |
| 5.B. | Biological treatment of solid waste | | N2O | 8.5 | 8.5 | 0.00 | 99.99 |
| 2.C.5. | Lead Production | | CO2 | 8.1 | 8.1 | 0.00 | 99.99 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | N2O | 6.7 | 6.7 | 0.00 | 99.99 |
| 2.B.5. | Carbide production | | CO2 | 6.2 | 6.2 | 0.00 | 99.99 |
| 1.B.2.a | Oil | | CO2 | 4.1 | 4.1 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Liquid fuels | N2O | 3.3 | 3.3 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Other fossil fuels | N2O | 3.1 | 3.1 | 0.00 | 100.00 |
| 1.B.2.b | Natural Gas | | CO2 | 2.5 | 2.5 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CH4 | 2.0 | 2.0 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Other fossil fuels | CH4 | 1.9 | 1.9 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Liquid fuels | CH4 | 1.9 | 1.9 | 0.00 | 100.00 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | N2O | 1.8 | 1.8 | 0.00 | 100.00 |

**Table A3 Key category analysis level assessment without LULUCF, 2018 (cont'd)**

| | Sector | Fuel | GAS | 2018 Emission | ABS (Emission) | Cont. (%) | Cumulative |
|---|---|---|---|---|---|---|---|
| 1.A.3.a. | Domestic Aviation | | CH4 | 1.7 | 1.7 | 0.00 | 100.00 |
| 5.C. | Incineration and open burning of waste | | CO2 | 1.2 | 1.2 | 0.00 | 100.00 |
| 2.B.8. | Petrochemical and carbon black production | | CO2 | 1.2 | 1.2 | 0.00 | 100.00 |
| 5.C. | Incineration and open burning of waste | | CH4 | 1.0 | 1.0 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Biomass | CH4 | 1.0 | 1.0 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | N2O | 0.8 | 0.8 | 0.00 | 100.00 |
| 1.B.2.c | Venting and flaring | | N2O | 0.7 | 0.7 | 0.00 | 100.00 |
| 1.A.3.c. | Railways | | CH4 | 0.6 | 0.6 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | N2O | 0.3 | 0.3 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | CH4 | 0.2 | 0.2 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CH4 | 0.2 | 0.2 | 0.00 | 100.00 |
| 5.C. | Incineration and open burning of waste | | N2O | 0.2 | 0.2 | 0.00 | 100.00 |
| 1.C. | CO2 Transport and storage | | CO2 | 0.1 | 0.1 | 0.00 | 100.00 |
| 2.E.5. | Other | | HFC | 0.1 | 0.1 | 0.00 | 100.00 |
| 2.E.5. | Other | | PFC | 0.0 | 0.0 | 0.00 | 100.00 |
| **Total** | | | | **520 941.59** | **520 941.59** | | |

**Table A4 Key category analysis trend assessment with LULUCF, 2018**

| | Sector | Fuel | Gas | 2018 | 1990 | Trend | Cont | Cum. |
|---|---|---|---|---|---|---|---|---|
| 4.A.1. | Forest Land Remaining Forest Land | | CO2 | -84 537.22 | -52 977.05 | 0.298 | 19.41 | 19.41 |
| 1.A.1. | Energy industries | Solid fuels | CO2 | 113 522.02 | 26 160.40 | 0.227 | 14.76 | 34.17 |
| 1.A.4. | Other sectors | Gaseous fuels | CO2 | 32 134.90 | 93.89 | 0.116 | 7.56 | 41.73 |
| 1.A.3.b. | Road Transportation | | CO2 | 77 289.17 | 24 142.97 | 0.109 | 7.12 | 48.85 |
| 1.A.1. | Energy industries | Gaseous fuels | CO2 | 38 793.87 | 5 024.67 | 0.105 | 6.85 | 55.70 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CO2 | 20 748.06 | 22 199.68 | 0.082 | 5.35 | 61.05 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CO2 | 21 831.56 | 1 557.79 | 0.068 | 4.44 | 65.50 |
| 2.A.1. | Cement Production (Mineral Products) | | CO2 | 37 025.70 | 10 444.54 | 0.060 | 3.93 | 69.43 |
| 1.A.4. | Other sectors | Liquid fuels | CO2 | 11 805.73 | 14 433.04 | 0.060 | 3.88 | 73.30 |
| 1.A.4. | Other sectors | Solid fuels | CO2 | 16 161.22 | 14 749.94 | 0.046 | 2.99 | 76.30 |
| 4.G. | Harvested Wood Products | | CO2 | -12 135.09 | -2 947.74 | 0.044 | 2.84 | 79.13 |
| 3.A. | Enteric fermentation | | CH4 | 32 059.81 | 22 314.09 | 0.042 | 2.73 | 81.86 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CO2 | 14 888.88 | 13 246.53 | 0.040 | 2.60 | 84.46 |
| 3.D.a. | Direct N2O emissions from managed soils | | N2O | 20 134.82 | 15 069.81 | 0.034 | 2.20 | 86.66 |
| 1.A.1. | Energy industries | Liquid fuels | CO2 | 4 758.75 | 5 945.25 | 0.025 | 1.62 | 88.28 |
| 2.F.6. | Other applications | | HFC | 4 866.45 | | 0.018 | 1.15 | 89.43 |
| 5.A. | Solid waste disposal | | CH4 | 8 863.89 | 6 729.60 | 0.016 | 1.01 | 90.45 |
| 1.A.4. | Other sectors | Biomass | CH4 | 488.41 | 2 263.35 | 0.014 | 0.93 | 91.38 |
| 5.D. | Wastewater treatment and discharge | | N2O | 6 091.03 | 1 440.99 | 0.012 | 0.77 | 92.15 |
| 5.D. | Wastewater treatment and discharge | | CH4 | 2 786.12 | 2 789.04 | 0.010 | 0.63 | 92.78 |
| 2.A.4. | Other process uses of carbonates | | CO2 | 3 356.33 | 618.97 | 0.008 | 0.51 | 93.29 |
| 1.B.1 | Solid fuels | | CH4 | 4 884.95 | 3 598.18 | 0.008 | 0.51 | 93.80 |
| 1.A.3.a. | Domestic Aviation | | CO2 | 3 648.13 | 913.74 | 0.007 | 0.44 | 94.24 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CO2 | 1 842.75 | | 0.007 | 0.44 | 94.67 |
| 2.A.2. | Lime Production (Mineral Products) | | CO2 | 2 786.68 | 2 248.84 | 0.006 | 0.38 | 95.05 |
| 3.D.b. | Indirect N2O Emissions from managed soils | | N2O | 2 561.80 | 2 125.94 | 0.006 | 0.38 | 95.43 |
| 1.B.2.b | Natural Gas | | CH4 | 1 826.04 | 143.70 | 0.006 | 0.37 | 95.80 |
| 3.B. | Manure management | | N2O | 4 556.67 | 3 080.16 | 0.005 | 0.35 | 96.14 |
| 2.C.3. | Aluminium Production | | PFC | 36.61 | 625.30 | 0.004 | 0.28 | 96.42 |
| 1.A.4. | Other sectors | Solid fuels | CH4 | 952.55 | 1 023.23 | 0.004 | 0.25 | 96.67 |
| 1.A.3.c. | Railways | | CO2 | 388.35 | 651.19 | 0.003 | 0.21 | 96.88 |
| 3.B. | Manure management | | CH4 | 3 886.27 | 2 352.09 | 0.003 | 0.17 | 97.05 |
| 4.C.2. | Land Converted to Grassland | | CO2 | 698.83 | | 0.003 | 0.17 | 97.21 |
| 2.C.1. | Iron and Steel Production | | CO2 | 12 536.60 | 6 766.59 | 0.002 | 0.16 | 97.37 |

**Table A4 Key category analysis trend assessment with LULUCF, 2018 (cont'd)**

| | Sector | Fuel | Gas | 2018 | 1990 | Trend | Cont | Cum. |
|---|---|---|---|---|---|---|---|---|
| 4.F.2. | Land Converted to Other Land | | CO2 | 650.08 | | 0.002 | 0.15 | 97.53 |
| 1.A.4. | Other sectors | Biomass | N2O | 77.62 | 359.72 | 0.002 | 0.15 | 97.67 |
| 1.A.1. | Energy industries | Gaseous fuels | N2O | 536.47 | 2.57 | 0.002 | 0.13 | 97.80 |
| 1.B.2.a | Oil | | CH4 | 331.78 | 419.87 | 0.002 | 0.12 | 97.92 |
| 1.A.3.e. | Other transportation | | CO2 | 541.39 | 39.29 | 0.002 | 0.11 | 98.02 |
| 4.B.2. | Land Converted to Cropland | | CO2 | 451.41 | | 0.002 | 0.11 | 98.13 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CO2 | 106.53 | 282.87 | 0.002 | 0.11 | 98.24 |
| 2.A.3. | Glass Production | | CO2 | 650.03 | 111.30 | 0.002 | 0.10 | 98.34 |
| 4.E.2. | Land Converted to Settlements | | CO2 | 406.90 | | 0.001 | 0.10 | 98.44 |
| 3.F. | Field burning of agricultural residues | | CH4 | 124.27 | 265.12 | 0.001 | 0.09 | 98.53 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CO2 | 814.28 | 220.75 | 0.001 | 0.09 | 98.62 |
| 4.A.2. | Land Converted to Forest Land | | CO2 | -340.19 | 20.70 | 0.001 | 0.09 | 98.71 |
| 1.A.1. | Energy industries | Other fossil fuels | CO2 | 368.64 | | 0.001 | 0.09 | 98.80 |
| 3.H. | Urea application | | CO2 | 1 257.47 | 459.95 | 0.001 | 0.08 | 98.88 |
| 1.A.4. | Other sectors | Liquid fuels | N2O | 1 066.21 | 692.17 | 0.001 | 0.07 | 98.95 |
| 1.B.2.c | Venting and flaring | | CO2 | 167.86 | 217.58 | 0.001 | 0.06 | 99.01 |
| 1.A.1. | Energy industries | Solid fuels | N2O | 444.77 | 96.75 | 0.001 | 0.06 | 99.07 |
| 2.B.2. | Nitric acid production | | N2O | 1 823.20 | 1 063.63 | 0.001 | 0.06 | 99.13 |
| 2.B.7. | Soda ash production | | CO2 | 224.44 | | 0.001 | 0.05 | 99.18 |
| 4.D.2. | Land Converted to Wetlands | | CO2 | 218.24 | | 0.001 | 0.05 | 99.24 |
| 2.F.3. | Fire protection | | HFC | 215.35 | | 0.001 | 0.05 | 99.29 |
| 2.B.1. | Ammonia Production | | CO2 | 1 038.39 | 424.76 | 0.001 | 0.05 | 99.34 |
| 1.A.3.b. | Road Transportation | | CH4 | 391.56 | 96.49 | 0.001 | 0.05 | 99.38 |
| 1.B.2.c | Venting and flaring | | CH4 | 443.90 | 126.99 | 0.001 | 0.05 | 99.43 |
| 1.A.3.b. | Road Transportation | | N2O | 1 226.50 | 537.71 | 0.001 | 0.04 | 99.47 |
| 2.B.8. | Petrochemical and carbon black production | | CO2 | 1.19 | 81.49 | 0.001 | 0.04 | 99.51 |
| 2.D.1. | Lubricant Use | | CO2 | 193.39 | 175.11 | 0.001 | 0.04 | 99.54 |
| 5.C. | Incineration and open burning of waste | | CH4 | 1.00 | 67.31 | 0.000 | 0.03 | 99.57 |
| 4.A.1. | Forest Land Remaining Forest Land | | CH4 | 16.61 | 74.60 | 0.000 | 0.03 | 99.61 |
| 3.F. | Field burning of agricultural residues | | N2O | 38.40 | 81.93 | 0.000 | 0.03 | 99.63 |
| 4.B.1. | Cropland Remaining Cropland | | CO2 | -116.81 | 0.69 | 0.000 | 0.03 | 99.66 |
| 2.B.5. | Carbide production | | CO2 | 6.23 | 58.99 | 0.000 | 0.03 | 99.69 |
| 1.A.3.c. | Railways | | N2O | 45.79 | 68.71 | 0.000 | 0.02 | 99.71 |
| 2.C.3. | Aluminium Production | | CO2 | 107.35 | 99.16 | 0.000 | 0.02 | 99.73 |

**Table A4 Key category analysis trend assessment with LULUCF, 2018 (cont'd)**

| | Sector | Fuel | Gas | 2018 | 1990 | Trend | Cont | Cum. |
|---|---|---|---|---|---|---|---|---|
| 4.A.1. | Forest Land Remaining Forest Land | | N2O | 10.95 | 49.19 | 0.000 | 0.02 | 99.75 |
| 2.C.6. | Zinc Production | | CO2 | | 37.84 | 0.000 | 0.02 | 99.77 |
| 1.A.4. | Other sectors | Gaseous fuels | CH4 | 72.68 | 0.21 | 0.000 | 0.02 | 99.78 |
| 2.G.1. | Electrical equipment | | SF6 | 71.39 | | 0.000 | 0.02 | 99.80 |
| 4.(IV).2. | Indirect N2O Emissions from nitrogen leaching and run-off | | N2O | 70.48 | | 0.000 | 0.02 | 99.82 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | N2O | 1.75 | 30.11 | 0.000 | 0.01 | 99.83 |
| 2.E.5. | Other | | SF6 | 57.00 | | 0.000 | 0.01 | 99.84 |
| 3.C. | Rice cultivation | | CH4 | 252.37 | 100.19 | 0.000 | 0.01 | 99.86 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | N2O | 87.72 | 72.60 | 0.000 | 0.01 | 99.87 |
| 5.C. | Incineration and open burning of waste | | CO2 | 1.24 | 26.59 | 0.000 | 0.01 | 99.88 |
| 2.C.2. | Ferroalloys Production | | CO2 | 169.84 | 61.56 | 0.000 | 0.01 | 99.89 |
| 1.A.4. | Other sectors | Solid fuels | N2O | 72.91 | 61.00 | 0.000 | 0.01 | 99.91 |
| 1.A.2. | Manufacturing industries and construction | Biomass | N2O | 41.59 | | 0.000 | 0.01 | 99.92 |
| 1.A.4. | Other sectors | Liquid fuels | CH4 | 19.16 | 30.81 | 0.000 | 0.01 | 99.92 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CH4 | 49.21 | 40.84 | 0.000 | 0.01 | 99.93 |
| 1.A.2. | Manufacturing industries and construction | Biomass | CH4 | 26.17 | | 0.000 | 0.01 | 99.94 |
| 4.B.2. | Land Converted to Cropland | | N2O | 22.73 | | 0.000 | 0.01 | 99.94 |
| 5.C. | Incineration and open burning of waste | | N2O | 0.17 | 11.23 | 0.000 | 0.01 | 99.95 |
| 1.A.1. | Energy industries | Liquid fuels | N2O | 3.32 | 12.59 | 0.000 | 0.01 | 99.95 |
| 1.A.3.a. | Domestic Aviation | | N2O | 37.78 | 8.88 | 0.000 | 0.00 | 99.96 |
| 1.A.1. | Energy industries | Gaseous fuels | CH4 | 24.56 | 2.16 | 0.000 | 0.00 | 99.96 |
| 1.A.4. | Other sectors | Gaseous fuels | N2O | 17.33 | 0.05 | 0.000 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | N2O | 15.82 | | 0.000 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CH4 | 13.12 | 12.66 | 0.000 | 0.00 | 99.97 |
| 1.A.1. | Energy industries | Biomass | N2O | 10.21 | | 0.000 | 0.00 | 99.98 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | N2O | 11.77 | 0.84 | 0.000 | 0.00 | 99.98 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CH4 | 9.95 | | 0.000 | 0.00 | 99.98 |
| 1.A.1. | Energy industries | Solid fuels | CH4 | 19.89 | 5.74 | 0.000 | 0.00 | 99.98 |
| 4.C.2. | Land Converted to Grassland | | N2O | 8.66 | | 0.000 | 0.00 | 99.99 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CH4 | 9.87 | 0.70 | 0.000 | 0.00 | 99.99 |
| 5.B. | Biological treatment of solid waste | | CH4 | 11.92 | 9.37 | 0.000 | 0.00 | 99.99 |
| 5.B. | Biological treatment of solid waste | | N2O | 8.53 | 6.70 | 0.000 | 0.00 | 99.99 |
| 4.D.2. | Land Converted to Wetlands | | N2O | 4.03 | | 0.000 | 0.00 | 99.99 |
| 1.A.1. | Energy industries | Liquid fuels | CH4 | 1.93 | 3.05 | 0.000 | 0.00 | 99.99 |

**Table A4 Key category analysis trend assessment with LULUCF, 2018 (cont'd)**

| | Sector | Fuel | Gas | 2018 | 1990 | Trend | Cont | Cum. |
|---|---|---|---|---|---|---|---|---|
| 2.C.5. | Lead Production | | CO2 | 8.10 | 2.20 | 0.000 | 0.00 | 99.99 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | N2O | 0.82 | 2.15 | 0.000 | 0.00 | 99.99 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | N2O | 6.71 | 1.79 | 0.000 | 0.00 | 99.99 |
| 2.D.2. | Paraffin Wax Use | | CO2 | 12.97 | 8.25 | 0.000 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Other fossil fuels | N2O | 3.10 | | 0.000 | 0.00 | 100.00 |
| 4.A.2. | Land Converted to Forest Land | | CH4 | 0.38 | 1.55 | 0.000 | 0.00 | 100.00 |
| 1.B.2.b | Natural Gas | | CO2 | 2.51 | 0.25 | 0.000 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Other fossil fuels | CH4 | 1.95 | | 0.000 | 0.00 | 100.00 |
| 4.A.2. | Land Converted to Forest Land | | N2O | 0.25 | 1.02 | 0.000 | 0.00 | 100.00 |
| 2.C.1. | Iron and Steel Production | | CH4 | 17.15 | 7.89 | 0.000 | 0.00 | 100.00 |
| 1.A.3.c. | Railways | | CH4 | 0.56 | 0.86 | 0.000 | 0.00 | 100.00 |
| 1.B.2.c | Venting and flaring | | N2O | 0.71 | 0.91 | 0.000 | 0.00 | 100.00 |
| 1.A.3.a. | Domestic Aviation | | CH4 | 1.66 | 0.31 | 0.000 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CH4 | 0.24 | 0.63 | 0.000 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Biomass | CH4 | 0.99 | | 0.000 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CH4 | 1.97 | 0.53 | 0.000 | 0.00 | 100.00 |
| 1.B.2.a | Oil | | CO2 | 4.10 | 2.38 | 0.000 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | N2O | 0.29 | 0.02 | 0.000 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | CH4 | 0.24 | 0.02 | 0.000 | 0.00 | 100.00 |
| 1.C. | CO2 Transport and storage | | CO2 | 0.13 | 0.13 | 0.000 | 0.00 | 100.00 |
| 2.E.5. | Other | | HFC | 0.10 | | 0.000 | 0.00 | 100.00 |
| 2.B.8. | Petrochemical and carbon black production | | CH4 | | 0.05 | 0.000 | 0.00 | 100.00 |
| 4.C.1. | Grassland Remaining Grassland | | CO2 | 0.03 | 0.03 | 0.000 | 0.00 | 100.00 |
| 4.D.1.1. | Peat Extraction Remaining Peat Extraction | | CO2 | 0.04 | 0.01 | 0.000 | 0.00 | 100.00 |
| 2.E.5. | Other | | PFC | 0.01 | | 0.000 | 0.00 | 100.00 |
| | **Total** | | | **426 371.90** | **163 590.81** | **1.54** | **100.00** | |

**Table A5 Key category analysis trend assessment without LULUCF, 2018**

| | Sector | Fuel | Gas | 2018 | 1990 | Trend | Cont | Cum. |
|---|---|---|---|---|---|---|---|---|
| 1.A.1. | Energy industries | Solid fuels | CO2 | 113 522.02 | 26 160.40 | 0.227 | 19.17 | 19.17 |
| 1.A.4. | Other sectors | Gaseous fuels | CO2 | 32 134.90 | 93.89 | 0.116 | 9.82 | 28.99 |
| 1.A.3.b. | Road Transportation | | CO2 | 77 289.17 | 24 142.97 | 0.109 | 9.25 | 38.24 |
| 1.A.1. | Energy industries | Gaseous fuels | CO2 | 38 793.87 | 5 024.67 | 0.105 | 8.90 | 47.14 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CO2 | 20 748.06 | 22 199.68 | 0.082 | 6.95 | 54.09 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CO2 | 21 831.56 | 1 557.79 | 0.068 | 5.77 | 59.86 |
| 2.A.1. | Cement Production (Mineral Products) | | CO2 | 37 025.70 | 10 444.54 | 0.060 | 5.11 | 64.97 |
| 1.A.4. | Other sectors | Liquid fuels | CO2 | 11 805.73 | 14 433.04 | 0.060 | 5.04 | 70.00 |
| 1.A.4. | Other sectors | Solid fuels | CO2 | 16 161.22 | 14 749.94 | 0.046 | 3.89 | 73.89 |
| 3.A. | Enteric fermentation | | CH4 | 32 059.81 | 22 314.09 | 0.042 | 3.54 | 77.44 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CO2 | 14 888.88 | 13 246.53 | 0.040 | 3.38 | 80.81 |
| 3.D.a. | Direct N2O emissions from managed soils | | N2O | 20 134.82 | 15 069.81 | 0.034 | 2.86 | 83.67 |
| 1.A.1. | Energy industries | Liquid fuels | CO2 | 4 758.75 | 5 945.25 | 0.025 | 2.11 | 85.78 |
| 2.F.6. | Other applications | | HFC | 4 866.45 | | 0.018 | 1.49 | 87.27 |
| 5.A. | Solid waste disposal | | CH4 | 8 863.89 | 6 729.60 | 0.016 | 1.32 | 88.59 |
| 1.A.4. | Other sectors | Biomass | CH4 | 488.41 | 2 263.35 | 0.014 | 1.21 | 89.80 |
| 5.D. | Wastewater treatment and discharge | | N2O | 6 091.03 | 1 440.99 | 0.012 | 1.01 | 90.80 |
| 5.D. | Wastewater treatment and discharge | | CH4 | 2 786.12 | 2 789.04 | 0.010 | 0.82 | 91.62 |
| 2.A.4. | Other process uses of carbonates | | CO2 | 3 356.33 | 618.97 | 0.008 | 0.66 | 92.28 |
| 1.B.1 | Solid fuels | | CH4 | 4 884.95 | 3 598.18 | 0.008 | 0.66 | 92.94 |
| 1.A.3.a. | Domestic Aviation | | CO2 | 3 648.13 | 913.74 | 0.007 | 0.57 | 93.51 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CO2 | 1 842.75 | | 0.007 | 0.57 | 94.08 |
| 2.A.2. | Lime Production (Mineral Products) | | CO2 | 2 786.68 | 2 248.84 | 0.006 | 0.49 | 94.57 |
| 3.D.b. | Indirect N2O Emissions from managed soils | | N2O | 2 561.80 | 2 125.94 | 0.006 | 0.49 | 95.06 |
| 1.B.2.b | Natural Gas | | CH4 | 1 826.04 | 143.70 | 0.006 | 0.47 | 95.54 |
| 3.B. | Manure management | | N2O | 4 556.67 | 3 080.16 | 0.005 | 0.45 | 95.98 |
| 2.C.3. | Aluminium Production | | PFC | 36.61 | 625.30 | 0.004 | 0.36 | 96.35 |
| 1.A.4. | Other sectors | Solid fuels | CH4 | 952.55 | 1 023.23 | 0.004 | 0.32 | 96.67 |
| 1.A.3.c. | Railways | | CO2 | 388.35 | 651.19 | 0.003 | 0.27 | 96.94 |
| 3.B. | Manure management | | CH4 | 3 886.27 | 2 352.09 | 0.003 | 0.22 | 97.16 |
| 2.C.1. | Iron and Steel Production | | CO2 | 12 536.60 | 6 766.59 | 0.002 | 0.21 | 97.37 |
| 1.A.4. | Other sectors | Biomass | N2O | 77.62 | 359.72 | 0.002 | 0.19 | 97.56 |
| 1.A.1. | Energy industries | Gaseous fuels | N2O | 536.47 | 2.57 | 0.002 | 0.16 | 97.73 |
| 1.B.2.a | Oil | | CH4 | 331.78 | 419.87 | 0.002 | 0.15 | 97.88 |
| 1.A.3.e. | Other transportation | | CO2 | 541.39 | 39.29 | 0.002 | 0.14 | 98.02 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CO2 | 106.53 | 282.87 | 0.002 | 0.14 | 98.16 |

**Table A5 Key category analysis trend assessment without LULUCF, 2018 (cont'd)**

| | Sector | Fuel | Gas | 2018 | 1990 | Trend | Cont | Cum. |
|---|---|---|---|---|---|---|---|---|
| 2.A.3. | Glass Production | | CO2 | 650.03 | 111.30 | 0.002 | 0.13 | 98.29 |
| 3.F. | Field burning of agricultural residues | | CH4 | 124.27 | 265.12 | 0.001 | 0.12 | 98.41 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CO2 | 814.28 | 220.75 | 0.001 | 0.12 | 98.53 |
| 1.A.1. | Energy industries | Other fossil fuels | CO2 | 368.64 | | 0.001 | 0.11 | 98.64 |
| 3.H. | Urea application | | CO2 | 1 257.47 | 459.95 | 0.001 | 0.11 | 98.75 |
| 1.A.4. | Other sectors | Liquid fuels | N2O | 1 066.21 | 692.17 | 0.001 | 0.09 | 98.84 |
| 1.B.2.c | Venting and flaring | | CO2 | 167.86 | 217.58 | 0.001 | 0.08 | 98.92 |
| 1.A.1. | Energy industries | Solid fuels | N2O | 444.77 | 96.75 | 0.001 | 0.08 | 99.00 |
| 2.B.2. | Nitric acid production | | N2O | 1 823.20 | 1 063.63 | 0.001 | 0.08 | 99.07 |
| 2.B.7. | Soda ash production | | CO2 | 224.44 | | 0.001 | 0.07 | 99.14 |
| 2.F.3. | Fire protection | | HFC | 215.35 | | 0.001 | 0.07 | 99.21 |
| 2.B.1. | Ammonia Production | | CO2 | 1 038.39 | 424.76 | 0.001 | 0.06 | 99.27 |
| 1.A.3.b. | Road Transportation | | CH4 | 391.56 | 96.49 | 0.001 | 0.06 | 99.34 |
| 1.B.2.c | Venting and flaring | | CH4 | 443.90 | 126.99 | 0.001 | 0.06 | 99.40 |
| 1.A.3.b. | Road Transportation | | N2O | 1 226.50 | 537.71 | 0.001 | 0.05 | 99.45 |
| 2.B.8. | Petrochemical and carbon black production | | CO2 | 1.19 | 81.49 | 0.001 | 0.05 | 99.50 |
| 2.D.1. | Lubricant Use | | CO2 | 193.39 | 175.11 | 0.001 | 0.05 | 99.54 |
| 5.C. | Incineration and open burning of waste | | CH4 | 1.00 | 67.31 | 0.000 | 0.04 | 99.58 |
| 3.F. | Field burning of agricultural residues | | N2O | 38.40 | 81.93 | 0.000 | 0.04 | 99.62 |
| 2.B.5. | Carbide production | | CO2 | 6.23 | 58.99 | 0.000 | 0.03 | 99.65 |
| 1.A.3.c. | Railways | | N2O | 45.79 | 68.71 | 0.000 | 0.03 | 99.68 |
| 2.C.3. | Aluminium Production | | CO2 | 107.35 | 99.16 | 0.000 | 0.03 | 99.71 |
| 2.C.6. | Zinc Production | | CO2 | | 37.84 | 0.000 | 0.02 | 99.73 |
| 1.A.4. | Other sectors | Gaseous fuels | CH4 | 72.68 | 0.21 | 0.000 | 0.02 | 99.75 |
| 2.G.1. | Electrical equipment | | SF6 | 71.39 | | 0.000 | 0.02 | 99.78 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | N2O | 1.75 | 30.11 | 0.000 | 0.02 | 99.79 |
| 2.E.5. | Other | | SF6 | 57.00 | | 0.000 | 0.02 | 99.81 |
| 3.C. | Rice cultivation | | CH4 | 252.37 | 100.19 | 0.000 | 0.02 | 99.83 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | N2O | 87.72 | 72.60 | 0.000 | 0.02 | 99.84 |
| 5.C. | Incineration and open burning of waste | | CO2 | 1.24 | 26.59 | 0.000 | 0.02 | 99.86 |
| 2.C.2. | Ferroalloys Production | | CO2 | 169.84 | 61.56 | 0.000 | 0.02 | 99.88 |
| 1.A.4. | Other sectors | Solid fuels | N2O | 72.91 | 61.00 | 0.000 | 0.01 | 99.89 |
| 1.A.2. | Manufacturing industries and construction | Biomass | N2O | 41.59 | | 0.000 | 0.01 | 99.90 |
| 1.A.4. | Other sectors | Liquid fuels | CH4 | 19.16 | 30.81 | 0.000 | 0.01 | 99.91 |
| 1.A.2. | Manufacturing industries and construction | Solid fuels | CH4 | 49.21 | 40.84 | 0.000 | 0.01 | 99.92 |
| 1.A.2. | Manufacturing industries and construction | Biomass | CH4 | 26.17 | | 0.000 | 0.01 | 99.93 |

**Table A5 Key category analysis trend assessment without LULUCF, 2018 (cont'd)**

| | Sector | Fuel | Gas | 2018 | 1990 | Trend | Cont | Cum. |
|---|---|---|---|---|---|---|---|---|
| 5.C. | Incineration and open burning of waste | | N2O | 0.17 | 11.23 | 0.000 | 0.01 | 99.94 |
| 1.A.1. | Energy industries | Liquid fuels | N2O | 3.32 | 12.59 | 0.000 | 0.01 | 99.95 |
| 1.A.3.a. | Domestic Aviation | | N2O | 37.78 | 8.88 | 0.000 | 0.01 | 99.95 |
| 1.A.1. | Energy industries | Gaseous fuels | CH4 | 24.56 | 2.16 | 0.000 | 0.01 | 99.96 |
| 1.A.4. | Other sectors | Gaseous fuels | N2O | 17.33 | 0.05 | 0.000 | 0.01 | 99.96 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | N2O | 15.82 | | 0.000 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Liquid fuels | CH4 | 13.12 | 12.66 | 0.000 | 0.00 | 99.97 |
| 1.A.1. | Energy industries | Biomass | N2O | 10.21 | | 0.000 | 0.00 | 99.97 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | N2O | 11.77 | 0.84 | 0.000 | 0.00 | 99.98 |
| 1.A.2. | Manufacturing industries and construction | Other fossil fuels | CH4 | 9.95 | | 0.000 | 0.00 | 99.98 |
| 1.A.1. | Energy industries | Solid fuels | CH4 | 19.89 | 5.74 | 0.000 | 0.00 | 99.98 |
| 1.A.2. | Manufacturing industries and construction | Gaseous fuels | CH4 | 9.87 | 0.70 | 0.000 | 0.00 | 99.99 |
| 5.B. | Biological treatment of solid waste | | CH4 | 11.92 | 9.37 | 0.000 | 0.00 | 99.99 |
| 5.B. | Biological treatment of solid waste | | N2O | 8.53 | 6.70 | 0.000 | 0.00 | 99.99 |
| 1.A.1. | Energy industries | Liquid fuels | CH4 | 1.93 | 3.05 | 0.000 | 0.00 | 99.99 |
| 2.C.5. | Lead Production | | CO2 | 8.10 | 2.20 | 0.000 | 0.00 | 99.99 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | N2O | 0.82 | 2.15 | 0.000 | 0.00 | 99.99 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | N2O | 6.71 | 1.79 | 0.000 | 0.00 | 99.99 |
| 2.D.2. | Paraffin Wax Use | | CO2 | 12.97 | 8.25 | 0.000 | 0.00 | 99.99 |
| 1.A.1. | Energy industries | Other fossil fuels | N2O | 3.10 | | 0.000 | 0.00 | 100.00 |
| 1.B.2.b | Natural Gas | | CO2 | 2.51 | 0.25 | 0.000 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Other fossil fuels | CH4 | 1.95 | | 0.000 | 0.00 | 100.00 |
| 2.C.1. | Iron and Steel Production | | CH4 | 17.15 | 7.89 | 0.000 | 0.00 | 100.00 |
| 1.A.3.c. | Railways | | CH4 | 0.56 | 0.86 | 0.000 | 0.00 | 100.00 |
| 1.B.2.c | Venting and flaring | | N2O | 0.71 | 0.91 | 0.000 | 0.00 | 100.00 |
| 1.A.3.a. | Domestic Aviation | | CH4 | 1.66 | 0.31 | 0.000 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CH4 | 0.24 | 0.63 | 0.000 | 0.00 | 100.00 |
| 1.A.1. | Energy industries | Biomass | CH4 | 0.99 | | 0.000 | 0.00 | 100.00 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CH4 | 1.97 | 0.53 | 0.000 | 0.00 | 100.00 |
| 1.B.2.a | Oil | | CO2 | 4.10 | 2.38 | 0.000 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | N2O | 0.29 | 0.02 | 0.000 | 0.00 | 100.00 |
| 1.A.3.e. | Other transportation | | CH4 | 0.24 | 0.02 | 0.000 | 0.00 | 100.00 |
| 1.C. | CO2 Transport and storage | | CO2 | 0.13 | 0.13 | 0.000 | 0.00 | 100.00 |
| 2.E.5. | Other | | HFC | 0.10 | | 0.000 | 0.00 | 100.00 |
| 2.B.8. | Petrochemical and carbon black production | | CH4 | | 0.05 | 0.000 | 0.00 | 100.00 |
| 2.E.5. | Other | | PFC | 0.01 | | 0.000 | 0.00 | 100.00 |
| | **Total** | | | **520 941.59** | **219 367.81** | **1.18** | **100.00** | |

## Annex 2: Uncertainty

In 2019 submission, on the recommendation of the UNFCCC expert review team (ERT) in 2018 Turkey has undertaken a tier 2 uncertainty analysis. Therefore, Turkey has estimated uncertainties both with Approach 1 and Approach 2 (Monte Carlo Simulation) methods. Approach 1, based on the error propagation equations, and Approach 2, corresponding to the application of Monte Carlo analysis. In the IPCC Good Practice Guidance, two methodologies (Tier 1 and Tier 2) for combining uncertainties are defined. Tier 1 uses error propagation equations. The equations are appropriate, when uncertainties are relatively small, have normal distributions and have no significant covariance. Tier 2 is more sophisticated method using Monte Carlo simulation. However, according to the IPCC Good Practice Guidance (Penman et al. 2000), countries performing an uncertainty analysis according to Tier 2 should also report the Tier 1 results. Turkey considered the Uncertainy results in both Approaches for prioritizing category improvements. Especially sectors with large AD or EF uncertainties, even if they are not key categories, have been treated as key categories and more precise information has been collected on those sub-categories primarily. In order to do this, both Approach 1 and Approach 2 results are evaluated together.

Table A6 shows Approach 1 results using the Table 3.2 of volume 1 of the 2006 IPCC Guidelines for now, but after generating MC simulation for entire inventory it is being planned to use Table 3.3 of volume 1 in IPCC Guidelines.

In this submission, Approach 2 was implemented to whole IPPU sector for 2018 emission levels with SPSS Modeler 18.2 software. In 2019 submission, Approach 2 was implemented to whole waste sector and some specific sub-sectors in energy, IPPU and agriculture sector. *(The main reasons of selected categories are their large shares of in total emissions and it is thought that first uncertainty method calculations require quality control for some of them primarily in order to provide category improvements.)* Those specific categories are shown at the summary table below in Table A7. And also the new study results on MC simulation for whole IPPU sector are added to Table A7. Moreover, the comparisons between Approach 1 and Approach 2 can easily be seen there.

In next year's submission, it is planning to be added energy sector to Approach 2 calculations and more details will be provided in the next NIR.

In Monte Carlo simulation, random numbers are selected from each distribution (for example, from probability distributions of activity data and emission factors) with means of uncertainties of Approach

1, and the total emissions are calculated ten thousand to one hundred thousand of times to obtain the probability distribution of total emissions depending on the opinion of the expert conducting the study. In this MC simulation for emission uncertainties, the selected precisions were obtained after about 100.000 trials.

Monte Carlo simulation allows the use of asymmetrical distributions. Normal distribution is the most widely used distribution for uncertainties. It is symmetrical around the mean and defined for all values. However, because emissions cannot be negative, normal distribution is used only in the cases where uncertainty is lower than ±100%. Normal distribution is a two-parametrical distribution and can therefore be completely described with the 95% confidence interval. Moreover, some sub-categories are defined with the PDF of lognormal distribution. E.g.: Urea application and Biological treatment of solid waste because of single-sided uncertainty distribution of ADs or EFs. Lognormal distribution is positively skewed, and it is defined only for positive values, which makes it very useful in describing emissions. Lognormal distribution is a transformation of normal distribution and is therefore also a two-parametric distribution. A combination of Monte Carlo and Bootstrap simulation was applied also some categories, in consideration of the specific data availability assuming a normal distribution for activity data and for the emission factor of natural gas. In 2020 submission, for entire IPPU sector, all distributions assumed as normal distribution.

According to the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Emission Inventories is "a system of routine technical activities, to measure and control the quality of the inventory as it is being developed". The QC system is designed to provide routine and consistent checks to ensure data integrity, correctness and completeness, to identify and address errors and emissions and to document and archive inventory material and record all QC activities. Therefore, Monte Carlo is a way of QC procedure. And, for the categories with a high uncertainty, generally, further improvements are planned whenever sectoral studies can be carried out.

Throughout the entire time series, the uncertainties associated with annual estimates are expressed as a 95% confidence interval, bound by 2.5$^{th}$ and 97.5$^{th}$ percentiles of the Monte Carlo run outputs as can be seen at the end of this chapter from histograms of uncertainties.

**Table A6 Approach 1 Uncertainty assessment**

| Source Category | | Fuel | Gas | Emissions in 1990 Gg $CO_2$eq | Emissions in 2018 Gg $CO_2$eq | AD Unc. % | EF Unc. % | Combined Unc. % | H(1) % | I(2) % | J(3) % | K(4) % | L(5) % | M(6) % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.A.1.a. | Public Electricity and Heat Production | Liquid fuels | $CO_2$ | 3 650.2 | 517.0 | 1.0 | 4.1 | 4.2 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.1 |
| 1.A.1.a. | Public Electricity and Heat Production | Solid fuels | $CO_2$ | 24 147.7 | 111 198.6 | 1.0 | 3.4 | 3.5 | 0.8 | 0.3 | 0.7 | 1.0 | 1.0 | 1.9 |
| 1.A.1.a. | Public Electricity and Heat Production | Gaseous fuels | $CO_2$ | 5 024.7 | 36 907.8 | 1.0 | 1.1 | 1.5 | 0.0 | 0.1 | 0.2 | 0.2 | 0.3 | 0.1 |
| 1.A.1.a. | Public Electricity and Heat Production | Other fossil fuels | $CO_2$ | | 368.6 | 18.0 | 9.6 | 20.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 1.A.1.b. | Petroleum Refining | Liquid fuels | $CO_2$ | 2 280.4 | 4 241.8 | 2.0 | 7.0 | 7.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| 1.A.1.b. | Petroleum Refining | Gaseous fuels | $CO_2$ | | 1 886.0 | 2.0 | 7.0 | 7.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.A.1.c. | Manufacture of solid fuels | | $CO_2$ | 2 027.4 | 2 323.4 | 2.0 | 7.0 | 7.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Liquid fuels | $CO_2$ | 1 823.3 | 22.4 | 10.0 | 7.0 | 12.2 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Solid fuels | $CO_2$ | 4 854.8 | 1 476.1 | 10.0 | 7.0 | 12.2 | 0.0 | 0.1 | 0.0 | 0.5 | 0.1 | 0.2 |
| 1.A.2.a. | Iron and Steel Production | Gaseous fuels | $CO_2$ | | 2 709.0 | 10.0 | 7.0 | 12.2 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.1 |
| 1.A.2.b. | Non-Ferrous Metals | Liquid fuels | $CO_2$ | 927.8 | 12.4 | 21.2 | 7.0 | 22.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.A.2.b. | Non-Ferrous Metals | Solid fuels | $CO_2$ | 156.3 | 219.7 | 21.2 | 7.0 | 22.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.b. | Non-Ferrous Metals | Gaseous fuels | $CO_2$ | | 574.8 | 21.2 | 7.0 | 22.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 1.A.2.c. | Chemicals | Liquid fuels | $CO_2$ | 2 588.1 | 26.9 | 15.8 | 7.0 | 17.3 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.1 |
| 1.A.2.c. | Chemicals | Solid fuels | $CO_2$ | 1 342.6 | 1 982.9 | 15.8 | 7.0 | 17.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.1 |
| 1.A.2.c. | Chemicals | Gaseous fuels | $CO_2$ | 944.6 | 4 987.2 | 15.8 | 7.0 | 17.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.7 | 0.5 |
| 1.A.2.c. | Chemicals | Other fossil fuels | $CO_2$ | | 13.1 | 2.0 | 7.0 | 7.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Liquid fuels | $CO_2$ | | 17.5 | 18.0 | 7.0 | 19.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Solid fuels | $CO_2$ | | 549.8 | 18.0 | 7.0 | 19.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Gaseous fuels | $CO_2$ | | 409.5 | 18.0 | 7.0 | 19.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Liquid fuels | $CO_2$ | 420.7 | 60.1 | 5.0 | 7.0 | 8.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Solid fuels | $CO_2$ | 2 471.7 | 2 427.0 | 18.0 | 7.0 | 19.3 | 0.0 | 0.0 | 0.0 | 0.2 | 0.4 | 0.2 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Gaseous fuels | $CO_2$ | | 2 559.8 | 14.1 | 7.0 | 15.8 | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.1 |
| 1.A.2.f. | Non metallic minerals | Liquid fuels | $CO_2$ | 2 626.3 | 13 899.5 | 27.8 | 7.0 | 28.7 | 0.9 | 0.0 | 0.1 | 0.3 | 3.3 | 11.2 |
| 1.A.2.f. | Non metallic minerals | Solid fuels | $CO_2$ | 5 587.5 | 10 379.2 | 25.5 | 7.0 | 26.4 | 0.4 | 0.0 | 0.1 | 0.2 | 2.3 | 5.3 |
| 1.A.2.f. | Non metallic minerals | Gaseous fuels | $CO_2$ | 1.9 | 3 939.8 | 29.2 | 7.0 | 30.0 | 0.1 | 0.0 | 0.0 | 0.2 | 1.0 | 1.0 |
| 1.A.2.f. | Non metallic minerals | Other fossil fuels | $CO_2$ | | 1 829.7 | 2.0 | 7.0 | 7.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Liquid Fuels | $CO_2$ | 4 860.3 | 850.0 | 70.7 | 7.0 | 71.1 | 0.0 | 0.1 | 0.0 | 0.5 | 0.5 | 0.5 |
| 1.A.2.g. | Other Industries | Solid Fuels | $CO_2$ | 7 786.9 | 3 713.5 | 70.7 | 7.0 | 71.1 | 0.4 | 0.1 | 0.0 | 0.7 | 2.3 | 5.7 |
| 1.A.2.g. | Other Industries | Gaseous Fuels | $CO_2$ | 611.2 | 6 651.5 | 70.7 | 7.0 | 71.1 | 1.2 | 0.0 | 0.0 | 0.2 | 4.1 | 16.6 |
| 1.A.3.a. | Domestic Aviation | Jet kerosene | $CO_2$ | 913.7 | 3 648.1 | 5.5 | 5.0 | 7.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 |
| 1.A.3.b. | Road Transportation | Gasoline | $CO_2$ | 8 377.4 | 6 780.3 | 10.1 | 5.0 | 11.2 | 0.0 | 0.1 | 0.0 | 0.5 | 0.6 | 0.6 |
| 1.A.3.b. | Road Transportation | Diesel oil | $CO_2$ | 15 765.5 | 60 536.6 | 10.1 | 5.0 | 11.2 | 2.5 | 0.1 | 0.4 | 0.6 | 5.3 | 28.0 |
| 1.A.3.b. | Road Transportation | Liquefied petroleum gases (LPG) | $CO_2$ | | 9 796.1 | 10.1 | 5.0 | 11.2 | 0.1 | 0.1 | 0.1 | 0.3 | 0.9 | 0.8 |
| 1.A.3.b. | Road Transportation | Gaseous fuels | $CO_2$ | | 176.2 | 10.0 | 7.0 | 12.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.c. | Railways | Liquid fuels | $CO_2$ | 589.5 | 388.3 | 2.0 | 1.5 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table A6 Approach 1 Uncertainty assessment**

| Source Category | | Fuel | Gas | Emissions in 1990 Gg $CO_2$eq | Emissions in 2018 Gg $CO_2$ eq | AD Unc. % | EF Unc. % | Combined Unc. % | H(1) % | I(2) % | J(3) % | K(4) % | L(5) % | M(6) % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.A.3.c. | Railways | Solid fuels | $CO_2$ | 61.7 | | 0.0 | 14.0 | 14.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | $CO_2$ | 282.9 | 106.5 | 15.0 | 3.0 | 15.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | $CO_2$ | 220.8 | 814.3 | 15.0 | 1.5 | 15.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 1.A.3.e. | Pipeline Transportation | Gaseous fuels | $CO_2$ | 39.3 | 541.4 | 5.0 | 7.0 | 8.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Liquid fuels | $CO_2$ | | 2 198.7 | 7.1 | 7.0 | 10.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Solid fuels | $CO_2$ | | 3 657.3 | 14.1 | 7.0 | 15.7 | 0.0 | 0.0 | 0.0 | 0.2 | 0.4 | 0.2 |
| 1.A.4.a. | Commercial/institutional | Gaseous fuels | $CO_2$ | | 7 628.2 | 5.0 | 7.0 | 8.6 | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 | 0.2 |
| 1.A.4.b. | Residential | Liquid fuels | $CO_2$ | 8 663.4 | 584.8 | 7.1 | 7.0 | 10.0 | 0.0 | 0.1 | 0.0 | 0.9 | 0.0 | 0.9 |
| 1.A.4.b. | Residential | Solid fuels | $CO_2$ | 14 749.9 | 12 503.9 | 14.1 | 7.0 | 15.7 | 0.2 | 0.2 | 0.1 | 1.1 | 1.5 | 3.6 |
| 1.A.4.b. | Residential | Gaseous fuels | $CO_2$ | 93.9 | 24 103.1 | 5.0 | 7.0 | 8.6 | 0.2 | 0.1 | 0.1 | 1.0 | 1.0 | 2.1 |
| 1.A.4.c. | Agriculture/Forestry/Fisheries | Liquid fuels | $CO_2$ | 5 769.6 | 9 022.2 | 14.1 | 5.0 | 15.0 | 0.1 | 0.0 | 0.1 | 0.2 | 1.1 | 1.2 |
| 1.A.4.c. | Agriculture/Forestry/Fisheries | Gaseous fuels | $CO_2$ | | 403.6 | 7.0 | 7.0 | 9.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.B.2.a. | Oil | | $CO_2$ | 2.4 | 4.1 | 7.0 | 50.0 | 50.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.B.2.b. | Natural gas | | $CO_2$ | 0.3 | 2.5 | 7.0 | 50.0 | 50.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.B.2.c. | Venting and flaring | | $CO_2$ | 217.6 | 167.9 | 7.0 | 50.0 | 50.5 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.C | Transport of $CO_2$ | | $CO_2$ | 0.1 | 0.1 | 2.0 | 50.0 | 50.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.A.1. | Cement Production (Mineral Products) | | $CO_2$ | 10 444.5 | 37 025.7 | 5.0 | 2.0 | 5.4 | 0.2 | 0.1 | 0.2 | 0.1 | 1.6 | 2.6 |
| 2.A.2. | Lime Production (Mineral Products) | | $CO_2$ | 2 248.8 | 2 786.7 | 10.0 | 10.0 | 14.1 | 0.0 | 0.0 | 0.0 | 0.2 | 0.2 | 0.1 |
| 2.A.3. | Glass Production | | $CO_2$ | 111.3 | 650.0 | 5.0 | 2.0 | 5.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.A.4. | Other process uses of carbonates | | $CO_2$ | 619.0 | 3 356.3 | 30.0 | 2.0 | 30.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.9 | 0.8 |
| 2.B.1. | Ammonia Production | | $CO_2$ | 424.8 | 1 038.4 | 2.0 | 5.0 | 5.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.B.5. | Carbide production | | $CO_2$ | 59.0 | 6.2 | 5.0 | 20.0 | 20.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.B.7. | Soda ash production | | $CO_2$ | | 224.4 | 5.0 | 1.0 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.B.8. | Petrochemical and carbon black production | | CO2 | $CO_2$ | 81.5 | 1.2 | 10.0 | 10.0 | 14.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.C.1. | Iron and Steel Production | | $CO_2$ | 6 766.6 | 12 536.6 | 10.0 | 25.0 | 26.9 | 0.6 | 0.0 | 0.1 | 0.8 | 1.1 | 1.8 |
| 2.C.2. | Ferroalloys Production | | $CO_2$ | 61.6 | 169.8 | 5.0 | 25.0 | 25.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.C.3. | Aluminium Production | | $CO_2$ | 99.2 | 107.3 | 1.0 | 5.0 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.C.5. | Lead Production | | $CO_2$ | 2.2 | 8.1 | 25.0 | 20.0 | 32.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.C.6. | Zinc Production | | $CO_2$ | 37.8 | | 20.0 | 50.0 | 53.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.D.1. | Lubricant Use | | $CO_2$ | 175.1 | 193.4 | 25.0 | 50.0 | 55.9 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 2.D.2. | Paraffin Wax Use | | $CO_2$ | 8.3 | 13.0 | 25.0 | 100.0 | 103.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.H. | Urea application | | $CO_2$ | 459.9 | 1 257.5 | 10.0 | 50.0 | 51.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 4.A. | Forestland | | $CO_2$ | -52 956.4 | -84 877.4 | 75.7 | 4.5 | 75.8 | 227.8 | 0.3 | 0.5 | 1.5 | 55.5 | 3085.8 |
| 4.B. | Cropland | | $CO_2$ | 0.7 | 334.6 | 47.9 | 4.2 | 48.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 4.C. | Grassland | | $CO_2$ | 0.0 | 698.9 | 148.7 | 10.2 | 149.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.9 | 0.8 |
| 4.D. | Wetlands | | $CO_2$ | 0.0 | 218.3 | 85.9 | 3.9 | 86.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 |

**Table A6 Approach 1 Uncertainty assessment (cont'd)**

| Source Category | | Fuel | Gas | Emissions in 1990 Gg $CO_2$eq | Emissions in 2018 Gg $CO_2$eq | AD Unc. % | EF Unc. % | Combined Unc. % | H(1) % | I(2) % | J(3) % | K(4) % | L(5) % | M(6) % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.E. | Settlements | | $CO_2$ | | 406.9 | 25.7 | 4.0 | 26.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 4.F. | Other land | | $CO_2$ | | 650.1 | 15.6 | 3.8 | 16.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 4.G. | Harvested wood products | | $CO_2$ | -2 947.7 | -12 135.1 | 23.3 | 3.2 | 23.5 | 0.4 | 0.0 | 0.1 | 0.1 | 2.4 | 6.0 |
| 5.C. | Incineration and open burning of waste | | $CO_2$ | 26.6 | 1.2 | 30.4 | 40.0 | 50.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | **Total $CO_2$** | | | **95 605.1** | **324 491.0** | | | | | | | | | |
| 1.A.1.a. | Public Electricity and Heat Production | Liquid fuels | $CH_4$ | 1.2 | 0.1 | 6.0 | 25.0 | 25.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.a. | Public Electricity and Heat Production | Solid fuels | $CH_4$ | 5.3 | 19.6 | 1.0 | 25.0 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.a. | Public Electricity and Heat Production | Gaseous fuels | $CH_4$ | 2.2 | 23.7 | 3.0 | 25.0 | 25.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.a. | Public Electricity and Heat Production | Other fossil fuels | $CH_4$ | | 1.9 | 0.9 | 25.0 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.a. | Public Electricity and Heat Production | Biomass | $CH_4$ | | 1.0 | 0.9 | 25.0 | 25.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.b. | Petroleum Refining | Liquid fuels | $CH_4$ | 1.8 | 1.8 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.b. | Petroleum Refining | Gaseous fuels | $CH_4$ | | 0.9 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.c. | Manufacture of solid fuels | | $CH_4$ | 0.4 | 0.3 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Liquid fuels | $CH_4$ | 1.8 | 0.0 | 10.0 | 100.0 | 100.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Solid fuels | $CH_4$ | 0.7 | 0.7 | 10.0 | 100.0 | 100.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Gaseous fuels | $CH_4$ | | 1.2 | 10.0 | 100.0 | 100.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Biomass | $CH_4$ | | 1.4 | | | | | | | | | |
| 1.A.2.b. | Non-Ferrous Metals | Liquid fuels | $CH_4$ | 0.9 | 0.0 | 21.2 | 100.0 | 102.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.b. | Non-Ferrous Metals | Solid fuels | $CH_4$ | 0.3 | 0.5 | 21.2 | 100.0 | 102.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.b. | Non-Ferrous Metals | Gaseous fuels | $CH_4$ | | 0.3 | 21.2 | 100.0 | 102.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Liquid fuels | $CH_4$ | 2.5 | 0.0 | 15.8 | 100.0 | 101.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Solid fuels | $CH_4$ | 2.9 | 5.0 | 15.8 | 100.0 | 101.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Gaseous fuels | $CH_4$ | 0.4 | 2.3 | 15.8 | 100.0 | 101.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Other fossil fuels | $CH_4$ | | 0.1 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Biomass | $CH_4$ | | 0.9 | | | | | | | | | |
| 1.A.2.d. | Pulp, Paper and Print | Liquid fuels | $CH_4$ | | 0.0 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Solid fuels | $CH_4$ | | 1.3 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Gaseous fuels | $CH_4$ | | 0.2 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Biomass | $CH_4$ | | 0.3 | | | | | | | | | |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Liquid fuels | $CH_4$ | 0.4 | 12.4 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Solid fuels | $CH_4$ | 5.5 | 5.8 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Gaseous fuels | $CH_4$ | | 1.2 | 14.1 | 100.0 | 101.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Biomass | $CH_4$ | | 5.3 | | | | | | | | | |

**Table A6 Approach 1 Uncertainty assessment (cont'd)**

| Source Category | | Fuel | Gas | Emissions in 1990 Gg $CO_2$eq | Emissions in 2018 Gg $CO_2$eq | AD Unc. % | EF Unc. % | Combined Unc. % | H(1) % | I(2) % | J(3) % | K(4) % | L(5) % | M(6) % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.A.2.f. | Non metallic minerals | Liquid fuels | CH4 | 2.4 | | 27.8 | 100.0 | 103.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Solid fuels | CH4 | 13.6 | 26.8 | 25.5 | 100.0 | 103.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Gaseous fuels | CH4 | 0.0 | 1.8 | 29.2 | 100.0 | 104.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Other fossil fuels | CH4 | | 9.9 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Biomass | CH4 | | 11.7 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Liquid Fuels | CH4 | 4.7 | 0.7 | 70.7 | 100.0 | 122.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Solid Fuels | CH4 | 17.7 | 9.0 | 70.7 | 100.0 | 122.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Gaseous Fuels | CH4 | 0.3 | 3.0 | 70.7 | 100.0 | 122.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Biomass | CH4 | | 6.6 | | | | | | | | | |
| 1.A.3.a. | Domestic Aviation | Jet kerosene | CH4 | 0.3 | 1.7 | 5.5 | 80.0 | 80.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.b. | Road Transportation | Gasoline | CH4 | 75.6 | 61.1 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 |
| 1.A.3.b. | Road Transportation | Diesel oil | CH4 | 20.9 | 81.7 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.b. | Road Transportation | Liquefied petroleum gases (LPG) | CH4 | | 240.8 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.1 |
| 1.A.3.b. | Road Transportation | Gaseous fuels | CH4 | | 7.3 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.b. | Road Transportation | Biomass | CH4 | | 0.6 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.c. | Railways | Liquid fuels | CH4 | 0.8 | 0.6 | 5.0 | 105.0 | 105.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.c. | Railways | Solid fuels | CH4 | 0.0 | | 5.0 | 135.0 | 135.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | CH4 | 0.6 | 0.2 | 15.0 | 50.0 | 52.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | CH4 | 0.5 | 2.0 | 15.0 | 50.0 | 52.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.e. | Pipeline Transportation | Gaseous fuels | CH4 | 0.0 | 0.2 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Liquid fuels | CH4 | | 5.0 | 7.1 | 100.0 | 100.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Solid fuels | CH4 | | 9.3 | 14.1 | 100.0 | 101.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Gaseous fuels | CH4 | | 17.3 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.b. | Residential | Liquid fuels | CH4 | 22.5 | 1.2 | 7.1 | 100.0 | 100.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.b. | Residential | Solid fuels | CH4 | 1 023.2 | 943.2 | 14.1 | 100.0 | 101.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.1 | 1.1 |
| 1.A.4.b. | Residential | Gaseous fuels | CH4 | 0.2 | 54.5 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.b. | Residential | Biomass | CH4 | 2 263.4 | 488.4 | 300.0 | 100.0 | 316.2 | 0.1 | 0.0 | 0.0 | 3.3 | 1.3 | 12.5 |
| 1.A.4.c. | Agriculture/Forestry/Fisheries | Liquid fuels | CH4 | 8.3 | 13.0 | 200.0 | 250.0 | 320.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.c. | Agriculture/Forestry/Fisheries | Gaseous fuels | CH4 | | 0.9 | 7.0 | 100.0 | 100.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.B.1.a. | Coal mining and handling | | CH4 | 3 598.2 | 4 884.9 | 16.6 | 150.0 | 150.9 | 3.0 | 0.0 | 0.0 | 4.1 | 0.7 | 17.5 |
| 1.B.2.a. | Oil | | CH4 | 419.9 | 331.8 | 7.0 | 100.0 | 100.2 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.2 |
| 1.B.2.b. | Natural gas | | CH4 | 143.7 | 1 826.0 | 7.0 | 100.0 | 100.2 | 0.2 | 0.0 | 0.0 | 0.9 | 0.1 | 0.8 |
| 1.B.2.c. | Venting and flaring | | CH4 | 127.0 | 443.9 | 7.0 | 100.0 | 100.2 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 2.B.8. | Petrochemical and carbon black production | | CH4 | 0.0 | | 10.0 | 30.0 | 31.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.C.1. | Iron and Steel Production | | CH4 | 7.9 | 17.1 | 10.0 | 5.0 | 11.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.A. | Enteric fermentation | | CH4 | 22 314.1 | 32 059.8 | 8.6 | 12.1 | 14.8 | 1.2 | 0.2 | 0.2 | 1.9 | 2.4 | 9.4 |

**Table A6 Approach 1 Uncertainty assessment (cont'd)**

| Source Category | | Fuel | Gas | Emissions in 1990 Gg $CO_2$eq | Emissions in 2018 Gg $CO_2$eq | AD Unc. % | EF Unc. % | Combined Unc. % | H(1) % | I(2) % | J(3) % | K(4) % | L(5) % | M(6) % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.B. | Manure management | | $CH_4$ | 2 352.1 | 3 886.3 | 14.1 | 30.0 | 33.1 | 0.1 | 0.0 | 0.0 | 0.4 | 0.5 | 0.4 |
| 3.C. | Rice cultivation | | $CH_4$ | 100.2 | 252.4 | 5.0 | 76.7 | 76.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.F. | Field burning of agricultural residues | | $CH_4$ | 265.1 | 124.3 | 50.0 | 40.0 | 64.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| 4.A. | Forest land | | $CH_4$ | 76.1 | 17.0 | 23.5 | 1.7 | 23.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.A.1. | Managed waste disposal | | $CH_4$ | | 1 083.5 | 10.0 | 30.8 | 32.4 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.1 |
| 5.A.2. | Unmanaged waste disposal sites | | $CH_4$ | 6 729.6 | 7 780.4 | 30.0 | 38.1 | 48.5 | 0.8 | 0.1 | 0.0 | 2.3 | 2.0 | 9.2 |
| 5.B. | Biological treatment of solid waste | | $CH_4$ | 9.4 | 11.9 | 10.0 | 20.0 | 22.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5.C. | Incineration and open burning of waste | | $CH_4$ | 67.3 | 1.0 | 30.4 | 100.0 | 104.5 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 5.D.1 | Domestic wastewater | | $CH_4$ | 2 579.8 | 2 158.5 | 5.0 | 37.7 | 38.0 | 0.0 | 0.0 | 0.0 | 1.1 | 0.1 | 1.1 |
| 5.D.2 | Industrial wastewater | | $CH_4$ | 209.2 | 627.6 | 11.2 | 39.1 | 40.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| | **Total $CH_4$** | | | **42 481.2** | **57 593.1** | | | | | | | | | |
| 1.A.1.a. | Public Electricity and Heat Production | Liquid fuels | $N_2O$ | 8.5 | 0.6 | 6.0 | 75.0 | 75.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.a. | Public Electricity and Heat Production | Solid fuels | $N_2O$ | 95.2 | 444.4 | 1.0 | 75.0 | 75.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.A.1.a. | Public Electricity and Heat Production | Gaseous fuels | $N_2O$ | 2.6 | 535.4 | 3.0 | 75.0 | 75.1 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.1 |
| 1.A.1.a. | Public Electricity and Heat Production | Other fossil fuels | $N_2O$ | | 3.1 | 0.9 | 75.0 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.a. | Public Electricity and Heat Production | Biomass | $N_2O$ | | 10.2 | 0.9 | 75.0 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.b. | Petroleum Refining | Liquid fuels | $N_2O$ | 4.1 | 2.7 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.b. | Petroleum Refining | Gaseous fuels | $N_2O$ | | 1.1 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.1.c. | Manufacture of solid fuels | | $N_2O$ | 1.6 | 0.4 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Liquid fuels | $N_2O$ | 4.2 | 0.1 | 10.0 | 100.0 | 100.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Solid fuels | $N_2O$ | 0.8 | 1.0 | 10.0 | 100.0 | 100.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Gaseous fuels | $N_2O$ | | 1.5 | 10.0 | 100.0 | 100.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.a. | Iron and Steel Production | Biomass | $N_2O$ | | 2.2 | | | | | | | | | |
| 1.A.2.b. | Non-Ferrous Metals | Liquid fuels | $N_2O$ | 2.1 | 0.0 | 21.2 | 100.0 | 102.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.b. | Non-Ferrous Metals | Solid fuels | $N_2O$ | 0.6 | 0.9 | 21.2 | 100.0 | 102.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.b. | Non-Ferrous Metals | Gaseous fuels | $N_2O$ | | 0.3 | 21.2 | 100.0 | 102.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Liquid fuels | $N_2O$ | 6.1 | 0.1 | 15.8 | 100.0 | 101.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Solid fuels | $N_2O$ | 5.3 | 9.0 | 15.8 | 100.0 | 101.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Gaseous fuels | $N_2O$ | 0.5 | 2.7 | 15.8 | 100.0 | 101.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Other fossil fuels | $N_2O$ | | 0.1 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.c. | Chemicals | Biomass | $N_2O$ | | 1.4 | | | | | | | | | |

**Table A6 Approach 1 Uncertainty assessment (cont'd)**

| Source Category | | Fuel | Gas | Emissions in 1990 Gg $CO_2$eq | Emissions in 2018 Gg $CO_2$eq | AD Unc. % | EF Unc. % | Combined Unc. % | H(1) % | I(2) % | J(3) % | K(4) % | L(5) % | M(6) % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.A.2.d. | Pulp, Paper and Print | Liquid fuels | $N_2O$ | | 0.0 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Solid fuels | $N_2O$ | | 2.4 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Gaseous fuels | $N_2O$ | | 0.2 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.d. | Pulp, Paper and Print | Biomass | $N_2O$ | | 0.4 | | | | | | | | | |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Liquid fuels | $N_2O$ | 1.0 | 0.1 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Solid fuels | $N_2O$ | 9.9 | 10.5 | 18.0 | 100.0 | 101.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Gaseous fuels | $N_2O$ | | 1.4 | 14.1 | 100.0 | 101.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.e. | Food Processing, Beverages and Tobacco | Biomass | $N_2O$ | | 8.4 | | | | | | | | | |
| 1.A.2.f. | Non metallic minerals | Liquid fuels | $N_2O$ | 5.6 | | 27.8 | 100.0 | 103.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Solid fuels | $N_2O$ | 24.3 | 48.0 | 25.5 | 100.0 | 103.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Gaseous fuels | $N_2O$ | 0.0 | 2.1 | 29.2 | 100.0 | 104.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Other fossil fuels | $N_2O$ | | 15.7 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.f. | Non metallic minerals | Biomass | $N_2O$ | | 18.7 | 2.0 | 100.0 | 100.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Liquid Fuels | $N_2O$ | 11.1 | 1.5 | 70.7 | 100.0 | 122.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Solid Fuels | $N_2O$ | 31.7 | 16.0 | 70.7 | 100.0 | 122.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Gaseous Fuels | $N_2O$ | 0.3 | 3.6 | 70.7 | 100.0 | 122.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.2.g. | Other Industries | Biomass | $N_2O$ | | 10.4 | | | | | | | | | |
| 1.A.3.a. | Domestic Aviation | Jet kerosene | $N_2O$ | 8.9 | 37.8 | 5.5 | 85.0 | 85.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.b. | Road Transportation | Gasoline | $N_2O$ | 288.2 | 233.3 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.6 |
| 1.A.3.b. | Road Transportation | Diesel oil | $N_2O$ | 249.5 | 973.4 | 10.0 | 250.0 | 250.2 | 0.3 | 0.0 | 0.0 | 0.5 | 0.1 | 0.3 |
| 1.A.3.b. | Road Transportation | Liquefied petroleum gases (LPG) | $N_2O$ | | 9.3 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.b. | Road Transportation | Gaseous fuels | $N_2O$ | | 2.9 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.b. | Road Transportation | Biomass | $N_2O$ | | 7.7 | 10.0 | 250.0 | 250.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.c. | Railways | Liquid fuels | $N_2O$ | 68.4 | 45.8 | 5.0 | 142.0 | 142.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.A.3.c. | Railways | Solid fuels | $N_2O$ | 0.3 | | 5.0 | 150.0 | 150.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.d. | Domestic Navigation | Residual fuel oil | $N_2O$ | 2.1 | 0.8 | 15.0 | 140.0 | 140.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.d. | Domestic Navigation | Gas/diesel oil | $N_2O$ | 1.8 | 6.7 | 15.0 | 140.0 | 140.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.3.e. | Pipeline Transportation | Gaseous fuels | $N_2O$ | 0.0 | 0.3 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Liquid fuels | $N_2O$ | | 2.0 | 7.1 | 100.0 | 100.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Solid fuels | $N_2O$ | | 16.7 | 14.1 | 100.0 | 101.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.a. | Commercial/institutional | Gaseous fuels | $N_2O$ | | 4.1 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.b. | Residential | Liquid fuels | $N_2O$ | 11.8 | 0.3 | 7.1 | 100.0 | 100.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.b. | Residential | Solid fuels | $N_2O$ | 61.0 | 56.2 | 14.1 | 100.0 | 101.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| 1.A.4.b. | Residential | Gaseous fuels | $N_2O$ | 0.1 | 13.0 | 5.0 | 100.0 | 100.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.A.4.b. | Residential | Biomass | $N_2O$ | 359.7 | 77.6 | 300.0 | 100.0 | 316.2 | 0.0 | 0.0 | 0.0 | 0.5 | 0.2 | 0.3 |
| 1.A.4.c. | Agriculture/Forestry/Fisheries | Liquid fuels | $N_2O$ | 680.3 | 1 063.9 | 14.1 | 250.0 | 250.4 | 0.4 | 0.0 | 0.0 | 1.1 | 0.1 | 1.2 |
| 1.A.4.c. | Agriculture/Forestry/Fisheries | Gaseous fuels | $N_2O$ | | 0.2 | 7.0 | 100.0 | 100.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.B.2.c. | Venting and flaring | | $N_2O$ | 0.9 | 0.7 | 7.0 | 100.0 | 100.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

## Table A6 Approach 1 Uncertainty assessment (cont'd)

| Source Category | | Fuel | Gas | Emissions in 1990 Gg $CO_2$eq | Emissions in 2018 Gg $CO_2$eq | AD Unc. % | EF Unc. % | | Combined Unc. % | H(1) % | I(2) % | J(3) % | K(4) % | L(5) % | M(6) % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.B.2. | Nitric acid production | | $N_2O$ | 1 063.6 | 1 823.2 | 2.0 | 20.0 | 20.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 1 063.6 |
| 3.B. | Manure management | | $N_2O$ | 3 080.2 | 4 556.7 | 14.1 | 50.0 | 52.0 | 0.3 | 0.0 | 0.0 | 1.1 | 0.6 | 1.4 | 3 080.2 |
| 3.D. | Agricultural soils | | $N_2O$ | 17 195.8 | 22 696.6 | 19.6 | 93.9 | 95.9 | 26.1 | 0.1 | 0.1 | 12.7 | 3.8 | 175.6 | 17 195.8 |
| 3.F. | Field burning of agricultural residues | | $N_2O$ | 81.9 | 38.4 | 50.0 | 40.0 | 64.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 81.9 |
| 4.A. | Forest land | | $N_2O$ | 50.2 | 11.2 | 10.0 | 95.4 | 95.9 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 50.2 |
| 4.B. | Cropland | | $N_2O$ | | 22.7 | 10.0 | 74.3 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| 4.C | Grassland | | $N_2O$ | | 8.7 | 10.0 | 74.3 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| 4.D | Wetlands | | $N_2O$ | | 4.0 | 10.0 | 74.3 | 75.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | |
| 4(IV) | Indirect $N_2O$ emissions from managed soils | | $N_2O$ | | 70.5 | 10.0 | 387.4 | 387.5 | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | |
| 5.B. | Biological treatment of solid waste | | $N_2O$ | 6.7 | 8.5 | 10.0 | 20.0 | 22.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.7 |
| 5.C. | Incineration and open burning of waste | | $N_2O$ | 11.2 | 0.2 | 30.4 | 100.0 | 104.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.2 |
| 5.D.1 | Wastewater treatment and discharge | | $N_2O$ | 1 441.0 | 6 091.0 | 30.0 | 42.4 | 51.9 | 0.6 | 0.0 | 0.0 | 0.6 | 1.6 | 2.9 | 1 441.0 |
| | **Total $N_2O$** | | | **24 879.2** | **39 040.9** | | | | | | | | | | |
| 2.C.3. | Aluminium Production | | PFC | 625.3 | 36.6 | 25.0 | 5.0 | 25.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.C.3. |
| 2.E.5. | Other | | HFC | | 0.1 | 25.0 | 5.0 | 25.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.E.5. |
| 2.E.5. | Other | | PFC | | 0 | 25.0 | 5.0 | 25.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.E.5. |
| 2.E.5. | Other | | $SF_6$ | | 57.0 | 25.0 | 5.0 | 25.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.E.5. |
| 2.F.3. | Fire protection | | HFC | | 215.4 | 25.0 | 5.0 | 25.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.F.3. |
| 2.F.6. | Other applications | | HFC | | 4866.4 | 25.0 | 5.0 | 25.5 | 0.1 | 0.0 | 0.0 | 0.1 | 1.1 | 1.1 | 2.F.6. |
| 2.G.1. | Electrical equipment | | $SF_6$ | | 71.4 | 25.0 | 5.0 | 25.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.G.1. |
| | **Total HFC, PFC & SF6** | | | **625.3** | **8 195.0** | | | | | **0.5** | **0.2** | | | | **1.7** |
| **Total all gases with LULUCF** | | | | **163 590.8** | **426 371.9** | | | | | | | | | | |
| | | | | | | **Overall Unc.** | | **16.4** | | | **Trend Unc.** | | **58.4** | | |
| **Total all gases without LULUCF** | | | | **219 367.8** | **520 941.6** | | | | | | | | | | |
| | | | | | | **Overall Unc.** | | **5.3** | | | **Trend Unc.** | | **12.0** | | |

**(1) Contribution to Variance by Category in Year t**
**(2) Type A sensitivity**
**(3) Type B sensitivity**
**(4) Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty**
**(5) Uncertainty in trend in national emissions introduced by activity data uncertainty**
**(6) Uncertainty introduced into the trend in total national emissions**

**Table A7.1 Approach 2 Uncertainty assessment (Monte Carlo Simulation Method) for 2017**

| *Selected Sources* | | | | 2017 Emissions (kt) | Estimates of 2017 Emissions (Means) with MC (kt) | Combined Uncertainty (%) Approach 1 (±) | Combined Uncertainty (%) Approach 2 |
|---|---|---|---|---|---|---|---|
| 1.A.1.a. | Public Electricity and Heat Production | Liquid fuels | CO2 | 1232.24 | 1190.78 | 4.24 | ±2.65 |
| 1.A.1.a. | Public Electricity and Heat Production | Solid fuels | CO2 | 98081.63 | 102140.92 | 3.50 | -2.97, +2.91 |
| 1.A.1.a. | Public Electricity and Heat Production | Gaseous fuels | CO2 | 45136.77 | 44124.70 | 1.50 | -1.46, +1.47 |
| 2.A.1. | Cement Production (Mineral Products) | | CO2 | 37272.44 | 37270.42 | 5.39 | -4.97, +5.02 |
| 2.A.2. | Lime Production (Mineral Products) | | CO2 | 2683.98 | 2684.52 | 14.14 | -12.29, +12.90 |
| 3.H. | Urea application | | CO2 | 1449.63 | 1451.54 | 50.99 | -13.54, +14.70 |
| 5.C. | Incineration and open burning of waste | | CO2 | 1.91 | 1.91 | 50.24 | ±41.88 |
| 3.C. | Rice cultivation | | CH4 | 9.35 | 9.47 | 76.9 | -68.95, +70.43 |
| 5.A.1. | Managed waste disposal | | CH4 | 33.87 | 34.64 | 32.38 | -34.93, +34.82 |
| 5.A.2. | Unmanaged waste disposal sites | | CH4 | 329.29 | 327.05 | 48.49 | -46.85, +47.31 |
| 5.B. | Biological treatment of solid waste | | CH4 | 0.33 | 0.36 | 22.36 | ±22.22 |
| 5.C. | Incineration and open burning of waste | | CH4 | 0.07 | 0.07 | 104.52 | -85.71, +114.29 |
| 5.D.1 | Domestic wastewater | | CH4 | 77.02 | 77.04 | 38.03 | -40.16, +40.77 |
| 5.D.2 | Industrial wastewater | | CH4 | 20.97 | 24.15 | 40.67 | -32.71, +41.28 |
| 5.B. | Biological treatment of solid waste | | N2O | 0.02 | 0.02 | 22.36 | +50 |
| 5.C. | Incineration and open burning of waste | | N2O | 0.00 | 0.00 | 104.52 | -72.73, +100 |
| 5.D.1 | Wastewater treatment and discharge | | N2O | 19.49 | 19.48 | 51.94 | -24.38, +25.56 |

**Table A7.2 Approach 2 Uncertainty assessment (Monte Carlo Simulation Method) for 2018**

| IPPU Sector | | 2018 Emissions (kt) | Estimates of 2018 Emissions (Means) with MC (kt) | Combined Uncertainty (%) Approach 1 (±) | Combined Uncertainty (%) Approach 2 |
|---|---|---|---|---|---|
| 2.A.1. Cement Production (Mineral Products) | $CO_2$ | 37 025.7 | 37 027.0 | 5.39 | -5.35, +5.37 |
| 2.A.2. Lime Production (Mineral Products) | $CO_2$ | 2 786.7 | 2 789.5 | 14.14 | -16.87, +17.92 |
| 2.A.3. Glass Production | $CO_2$ | 650.0 | 650.1 | 5.39 | -9.63, +9.82 |
| 2.A.4. Other process uses of carbonates | $CO_2$ | 3 356.3 | 3 354.3 | 30.07 | -16.68, +17.81 |
| 2.B.1. Ammonia Production | $CO_2$ | 1 038.4 | 1 038.3 | 5.39 | -7.46, +7.54 |
| 2.B.5. Carbide production | $CO_2$ | 6.2 | 6.2 | 20.62 | -20.55, +20.87 |
| 2.B.7. Soda ash production | $CO_2$ | 224.4 | 224.4 | 5.10 | -5.10, +5.15 |
| 2.B.8. Petrochemical and carbon black production | $CO_2$ | 1.2 | 1.2 | 14.14 | ±14.29 |
| 2.C.1. Iron and Steel Production | $CO_2$ | 12 536.6 | 12 599.2 | 26.93 | -29.05, +29.32 |
| 2.C.2. Ferroalloys Production | $CO_2$ | 169.8 | 169.9 | 25.50 | -25.15, +25.52 |
| 2.C.3. Aluminium Production | $CO_2$ | 107.3 | 107.4 | 5.10 | -5.15, +5.16 |
| 2.C.5. Lead Production | $CO_2$ | 8.1 | 8.1 | 32.02 | -22.87, +24.60 |
| 2.D.1. Lubricant Use | $CO_2$ | 193.4 | 193.4 | 55.90 | -51.96, +59.43 |
| 2.D.2. Paraffin Wax Use | $CO_2$ | 13.0 | 13.0 | 103.08 | -98.46, +107.31 |
| 2.C.1. Iron and Steel Production | $CH_4$ | 17.1 | 17.3 | 11.18 | -13.04, +11.59 |
| 2.B.2. Nitric acid production | $N_2O$ | 1 823.2 | 1 823.8 | 20.10 | ±20.59 |

The probability density functions resulting from the Monte Carlo assessment are shown below:

**Figure A1 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Public Electricity and Heat Production - Liquid fuels in ENERGY sector, 2017**

**Figure A2 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Public Electricity and Heat Production - Solid fuels in ENERGY sector, 2017**

**Figure A3 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Public Electricity and Heat Production- Gaseous fuels in ENERGY sector, 2017**

**Figure A4 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Cement Production in IPPU sector, 2018**

**Figure A5 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Lime Production in IPPU sector, 2018**

**Figure A6 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Glass Production in IPPU sector, 2018**

**Figure A7 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Ceramics in IPPU sector, 2018**

**Figure A8 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Other Uses of Soda Ash in IPPU sector, 2018**

**Figure A9 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Non-Metallurgical Magnesia Production in IPPU sector, 2018**

**Figure A10 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Ammonia Production in IPPU sector, 2018**

**Figure A11 Probability density function resulting from Monte Carlo analysis for $N_2O$ emissions from Nitric Acid Production in IPPU sector, 2018**

**Figure A12 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Carpide Production in IPPU sector, 2018**

**Figure A13 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Soda Ash Production in IPPU sector, 2018**

**Figure A14 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Petrochemical and Carbon Black Production in IPPU sector, 2018**

**Figure A15 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Iron and Steel Production in IPPU sector, 2018**

**Figure A16 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Iron and Steel Production in IPPU sector, 2018**

**Figure A17 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Ferroalloys Production in IPPU sector, 2018**

**Figure A18 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Aluminum Production in IPPU sector, 2018**

**Figure A19 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Lead Production in IPPU sector, 2018**

**Figure A20 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Lubricant Use in IPPU sector, 2018**

**Figure A21 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Paraffin Wax Use in IPPU sector, 2018**

**Figure A22 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Urea Application in AGRICULTURE sector, 2017**

**Figure A23 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Rice Cultivation in AGRICULTURE sector, 2017**

**Figure A24 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Managed SWDS in WASTE sector, 2017**

**Figure A25 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Unmanaged SWDS in WASTE sector, 2017**

**Figure A26 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Biological Treatment of Solid Waste - Composting in WASTE sector, 2017**

**Figure A27 Probability density function resulting from Monte Carlo analysis for $N_2O$ emissions from Biological Treatment of Solid Waste - Composting in WASTE sector, 2017**

**Figure A28 Probability density function resulting from Monte Carlo analysis for $CO_2$ emissions from Incineration and Open Burning Of Waste in WASTE sector, 2017**

**Figure A29 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Incineration and Open Burning Of Waste in WASTE sector, 2017**

**Figure A30 Probability density function resulting from Monte Carlo analysis for $N_2O$ emissions from Incineration and Open Burning of Waste in WASTE sector, 2017**

**Figure A31 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Wastewater Treatment and Discharge- Industrial Wastewater in WASTE sector, 2017**

**Figure A32 Probability density function resulting from Monte Carlo analysis for $CH_4$ emissions from Wastewater Treatment and Discharge- Domestic Wastewater in WASTE sector, 2017**

**Figure A33 Probability density function resulting from Monte Carlo analysis for $N_2O$ emissions from Wastewater Treatment and Discharge- Domestic Wastewater in WASTE sector, 2017**

# Annex 3: Country Specific Carbon Content Determination and Emission Factors

In Turkey we do not have ETS registry yet. Therefore, in order to calculate country specific EFs, we lean on data obtained from a number of coal firing plants, BOTAŞ and some public university laboratories. Those analyses are the basis of country specific Carbon Contents.

### Natural gas

In order for carbon content of natural gas to be calculated, densities of gases included in it must be known to convert volumetric compositions to mass fractions.
Volumetric fractions of gas concentrations were obtained through gas chromatography analysis from Petroleum Pipeline Company (BOTAŞ). Using density of the gases and some stoichiometry carbon mass amount coming from each gas was calculated and summed up to reach an overall carbon amount. For gaseous fuels CO measured in the stack gas was used in order to calculate unoxidised carbon's mass percentage and then oxidation rate of the related fuel. In order to calculate the oxidation rate of gaseous fuels (natural gas), CO concentration measured in the stack gas of the related plants were obtained from the Ministry of Environment and Urbanization.

### Turkey Lignite

Ultimate analysis results, which were obtained from coal firing plants, were used to calculate carbon content of the related coal types. In the analysis results Carbon content together with, Hydrogen, Sulphur, Oxygen moisture, ash, volatile substances contents are measured. Also net and gross calorific values are provided in the same reports. Carbon contents and net calorific values (circulated figures in the below analysis report) are used for calculating carbon content of Turkey lignite.

Oxidation rate of solid fuels was calculated by using the mass percentage of carbon in ash-slag analysis reports which were obtained from coal firing plants.

### Hard coal

Carbon contents and oxidation rates of hard coal is calculated in the same way as in Turkey Lignite.
Country specific carbon content and oxidation rates of hard coal calculated based on power plants coal analysis are used for all 1.A categories.

### Coke oven coke

Country specific Carbon content of coke oven coke is calculated based on carbon content and net calorific values provided by the integrated iron&steel facilities in Turkey. There are 3 integrated iron&steel facilities in Turkey and there are coke production plants in all of them. Carbon contents of all carbonaceous material used for iron and steel production is measured by all the facilities. Carbon content of coke oven coke is also measured since it is used as reducing agent in pig iron production. Annual average carbon content of coke oven coke as kg C/ton of coke and net calorific values are compiled from integrated facilities. The mass of carbon is divided by net calorific values of coke oven coke and the result is the carbon content as kg C/GJ of coke. Calculated country specific carbon content is used for estimation of $CO_2$ emissions from coke combustion of all other sectors using coke as a fuel.

### Gas/diesel oil and Residual fuel oil

Carbon content of gas/diesel oil and residual fuel oil is calculated based on fuel analysis made by Petroleum Research Centre at Middle East Technical University (METU) in Ankara. The Research Center was founded by METU Petroleum Engineering Department and General Directorate of Petroleum Affairs (under the Ministry of Energy and Natural Resources). The main objective of the Center is to make research on the oil and gas exploration and production, refining and transportation and to conduct projects on topics requested by public and private organizations.

Based on the fuel analysis of Petroleum Research Center, an example for calculation of carbon content of gas diesel oil and residual fuel oil is given below.

| Sample A | Number of Sample B | C, normalized (%) C | NCV kcal/kg (average) D | NCV GJ/kg (average) E | C mass/kg fuel F (C/100) | C content kg C/GJ G (F/E) |
|---|---|---|---|---|---|---|
| **Diesel** | 639/06-1106 | 86.261 | 10233 | 0.0428435 | 0.86261 | 20.133975 |
| **Fuel Oil** | 255/06-330 | 86.611 | 9901 | 0,0414535 | 0.86611 | 20.893530 |

Source: METU, Petroleum Research Laboratory, 2006.

An example for oxidation rate for gas diesel oil and residual fuel oil;

Oxidation rate of gas/diesel oil and residual fuel oil is calculated based on stack gas analysis of oil fired power plants. In stack gas analysis, CO percentage in stack gas is measured. Based on the inlet carbon already provided in fuel analysis report and outlet C derived from stack gas analysis, oxidation rates are calculated.

An example calculation is given below.

| | | | |
|---|---|---|---|
| | | **Fuel oil density (kg/m3)** | 0.9757 |
| **CO (average v/v %)** | 3.25 | **C inlet (m/m) %** | 86.611 |
| **C (outlet v/v %) (*12/28)** | 1.39 | **C inlet (v/v) %** | 88.768 |

**Oxidation rate, %:** ((C inlet - C outlet)/C inlet)*100 = 98.43

### Petroleum coke

Petroleum coke is used in mostly in cement factories. There are around 50 cement factories in Turkey. Availability of fuel analysis report is asked to the factories via official letters. Net calorific values are available in most of the factories but a few of them has carbon content analysis. Averages of all available data are used as country specific carbon content of petroleum coke.

## Emissions Factors

### Emission Factors used for Energy Sector

| NCV of Fuels | | |
|---|---|---|
| | **2018** | **Unit** |
| Hard coal | 28.87 | TJ/kton |
| Lignite | 7.81 | TJ/kton |
| Asphaltite | 18.42 | TJ/kton |
| Coke | 27.00 | TJ/kton |
| BFG | 714 | Kcal/kg |
| Coke oven gas | 4 238 | Kcal/kg |
| BOF gas | 1 519 | Kcal/kg |
| Oil | 43.96 | TJ/kton |
| Coal tar | 37.25 | TJ/kton |
| Petroleum Coke | 32.24 | TJ/kton |
| Fuel oil | 43.34 | TJ/kton |
| Diesel oil | 43.33 | TJ/kton |
| Gasoline | 44.80 | TJ/kton |
| LPG | 47.31 | TJ/kton |
| Refinery gas | 48.15 | TJ/kton |
| Jet Kerosene | 44.59 | TJ/kton |
| Kerosene | 43.75 | TJ/kton |
| Naphtha | 45.01 | TJ/kton |
| By products | 40.19 | TJ/kton |
| Basic oil | 42.00 | TJ/kton |
| White spirit | 43.50 | TJ/kton |
| Bitumen | 40.19 | TJ/kton |
| Other petroleum products | 40.19 | TJ/kton |
| Natural gas | 34.54 | TJ/10^6m3 |
| Wood | 12.56 | TJ/kton |
| Crop and animal residue | 9.63 | TJ/kton |
| Biofuels | 36.05 | TJ/kton |

(TJ/kt) = (1000 TOE)/(kt) * 41.868

(TJ/10^6m3) = (1000 TOE)/(10^6m3) * 41.868

| | Country Specific $CO_2$ Emission Factor | | | | | | (kg/TJ) |
|---|---|---|---|---|---|---|---|
| Years | Hard Coal | Lignite | Coke | BFG | COG | BOF Gas | Natural Gas |
| 1990 | 93.37 | 114.16 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1991 | 101.38 | 114.01 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1992 | 101.35 | 113.85 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1993 | 100.54 | 113.70 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1994 | 99.12 | 113.54 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1995 | 102.17 | 113.39 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1996 | 102.50 | 113.23 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1997 | 103.34 | 113.08 | 110.29 | 258.85 | 40.46 | 176.53 | 55.61 |
| 1998 | 102.81 | 112.92 | 110.29 | 255.17 | 40.25 | 176.53 | 55.61 |
| 1999 | 93.39 | 112.77 | 110.29 | 255.17 | 40.27 | 176.53 | 55.61 |
| 2000 | 95.52 | 110.05 | 110.29 | 260.85 | 40.27 | 176.53 | 55.61 |
| 2001 | 99.28 | 110.58 | 110.29 | 261.55 | 40.90 | 176.53 | 55.61 |
| 2002 | 96.27 | 111.30 | 110.29 | 261.55 | 40.60 | 176.53 | 55.61 |
| 2003 | 100.90 | 112.00 | 110.70 | 261.55 | 41.51 | 176.53 | 55.65 |
| 2004 | 90.34 | 112.72 | 110.62 | 261.55 | 41.76 | 176.53 | 55.61 |
| 2005 | 94.23 | 113.50 | 112.25 | 256.64 | 43.40 | 176.53 | 55.60 |
| 2006 | 88.71 | 114.18 | 110.29 | 261.55 | 40.88 | 176.53 | 55.61 |
| 2007 | 88.52 | 113.62 | 111.97 | 264.06 | 41.41 | 176.53 | 55.62 |
| 2008 | 93.35 | 112.51 | 110.29 | 257.53 | 40.91 | 176.53 | 55.62 |
| 2009 | 96.03 | 111.39 | 111.58 | 259.33 | 41.85 | 175.60 | 55.68 |
| 2010 | 98.56 | 110.26 | 109.79 | 257.31 | 41.22 | 179.97 | 55.74 |
| 2011 | 95.10 | 109.48 | 110.05 | 257.81 | 39.36 | 174.71 | 56.31 |
| 2012 | 96.65 | 109.29 | 111.01 | 256.94 | 40.05 | 174.81 | 55.66 |
| 2013 | 96.18 | 109.09 | 112.45 | 252.27 | 42.12 | 176.39 | 55.66 |
| 2014 | 93.15 | 107.63 | 110.71 | 251.92 | 42.03 | 173.73 | 55.68 |
| 2015 | 92.38 | 107.63 | 110.38 | 258.70 | 40.78 | 175.09 | 55.75 |
| 2016 | 85.32 | 107.41 | 108.37 | 265.09 | 39.02 | 182.31 | 55.39 |
| 2017 | 94.50 | 107.24 | 112.22 | 264.12 | 37.45 | 190.08 | 55.62 |
| 2018 | 93.25 | 108.88 | 108.08 | 268.30 | 37.35 | 194.38 | 55.27 |

**Default $CO_2$ Emission Factors**

| Fuels | 1990-2018 |
|---|---|
| Sub bituminous coal | 96.1 |
| Coal tar | 80.7 |
| Crude oil | 73.3 |
| Petroleum Coke | 97.4 |
| Fuel Oil | 77.0 |
| Diesel Oil | 72.3 |
| Gasoline | 69.3 |
| LPG | 63.1 |
| Refinery gas | 57.6 |
| Jet kerosene | 71.5 |
| Kerosene | 71.9 |
| Naphtha | 72.7 |
| By products | 73.3 |
| Basic oil | 73.3 |
| White spirit | 73.3 |
| Bitumen | 80.7 |
| Other petroleum products | 73.3 |
| Navigation diesel oil | 72.3 |
| Navigation fuel | 77.0 |
| Wood | 111.8 |
| Biofuels and Waste | 100.1 |

**$CH_4$ and $N_2O$ Emission Factors**

| | Emission Factors | | Source |
|---|---|---|---|
| Sub Sectors | $CH_4$ (kg/TJ) | $N_2O$(kg/TJ) | |
| 1A1b sector | | | |
| Fuel oil | 3 | 0.6 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| Diesel oil | 3 | 0.6 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| Natural gas | 1 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| Rafinery gas | 1 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| FCC coke | 3 | 0.6 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |

| | Emission Factors | | Source |
|---|---|---|---|
| Sub Sectors | $CH_4$ (kg/TJ) | $N_2O$(kg/TJ) | |
| 1A1c sector | | | |
| Derived gases | 1 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |

**$CH_4$ and $N_2O$ Emission Factors (cont'd)**

| | Emission Factors | | Source |
|---|---|---|---|
| **Sub Sectors** | **$CH_4$ (kg/TJ)** | **$N_2O$(kg/TJ)** | |
| 1A2 sector | | | |
| Coal products | 10 | 1.5 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| LPG | 1 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| Other Petroleum products | 3 | 0.6 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| Derived gases | 1 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| Wood | 30 | 4 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |
| Natural gas | 1 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.3 page 2.18 |

| | Emission Factors | | Source |
|---|---|---|---|
| **Sub Sectors** | **$CH_4$ (kg/TJ)** | **$N_2O$(kg/TJ)** | |
| 1A4a sector | | | |
| Coal products | 10 | 1.5 | 2006 IPCC Guideline Vol2 Table 2.4 page 2.20 |
| LPG | 5 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.4 page 2.20 |
| Other petroleum products | 10 | 0.6 | 2006 IPCC Guideline Vol2 Table 2.4 page 2.20 |
| Wood | 300 | 4 | 2006 IPCC Guideline Vol2 Table 2.4 page 2.20 |
| Natural gas | 5 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.4 page 2.20 |
| 1A4b, 1A4c sectors | | | |
| Coal products | 300 | 1.5 | 2006 IPCC Guideline Vol2 Table 2.5 page 2.22 |
| LPG | 5 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.5 page 2.22 |
| Other petroleum products | 10 | 0.6 | 2006 IPCC Guideline Vol2 Table 2.5 page 2.22 |
| Wood | 300 | 4 | 2006 IPCC Guideline Vol2 Table 2.5 page 2.22 |
| Other primary solid biomass | 300 | 4 | 2006 IPCC Guideline Vol2 Table 2.5 page 2.22 |
| Natural gas | 5 | 0.1 | 2006 IPCC Guideline Vol2 Table 2.5 page 2.22 |

**Emission factors used for IPPU**

| Category | | EF | Reference |
|---|---|---|---|
| Cement Production | CKD | 1.02 | IPCC Default |
| | EF | 0.52 | CS |
| Lime Production | EF high calcium lime ((tonnes $CO_2$/tonne carbonate) | 0.69 | CS |
| | EF dolomitic lime (tonnes $CO_2$/tonne carbonate) | 0.77 | Default |
| Glass production/Ceramics/Roof and Tiles/ Soda ash use | Soda (tonnes $CO_2$/tonne carbonate) | 0.41 | IPCC Vol 2. Table 2.1. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf |
| | Dolomit (tonnes $CO_2$/tonne carbonate) | 0.48 | IPCC Vol 2. Table 2.1. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf |
| | Kalker (tonnes $CO_2$/tonne carbonate) | 0.44 | IPCC Vol 2. Table 2.1. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf |
| Magnesia Production | Magnesia (tonnes $CO_2$/tonne carbonate) | 0.52 | IPCC Vol 2. Table 2.1. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf |
| Ammonia Production | Natural Gas NCV (kcal/sm3) | 8396 | BOTAŞ |
| | Natural Gas NCV (GJ/sm3) | 0.0352 | BOTAŞ |
| | Nat Gas. Car. Cont. (kgC/GJ) | 15.1 | BOTAŞ |
| | Carbon Oxidation Factor | 1 | Default |
| Nitric Acid Production | Middle pressure plant (kg N2O/tonne nitric acid) | 7 | IPCC VOL 2. Table 3.3. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf |
| | with abatement technology(kg $N_2O$/tonne nitric acid) | 2.5 | IPCC VOL 2. Table 3.3. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf |
| Carpide Production | Carpide (tonnes $CO_2$/tonne carbide produced) | 1.09 | IPCC VOL 2. Table 3.8. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf |
| | Asetilen (tonnes $CO_2$/tonne carbide produced) | 1.1 | IPCC VOL 2. Table 3.8. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf |
| Soda Ash Production | Soda ash (tonnes $CO_2$/tonne of Trona) | 0.097 | IPCC VOL 2. Equation 3.4. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf |
| Petrochemicals | Fuel gas | 0.67227 | CS, Petkim |
| Iron and Steel Production | | | PS, confidential |
| Ferro chrome production | | 1.3 | IPCC VOL 2. Table 4.5 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf |
| Aluminium production | Net prebaked anode consumption (ton/ ton alüminyum) | 0.412 | PS |
| | Carbon content wt % | 98.56 | PS |
| Lead production | | 0.2 | IPCC VOL 2. Table 4.21 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf |
| Lubricant and paraffin wax use | Carbon content | 20 | IPCC VOL 2. Table 5.2 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_5_Ch5_Non_Energy_Products.pdf |
| | Oxidation rate | 0.2 | IPCC VOL 2. Equation 5.4 https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_5_Ch5_Non_Energy_Products.pdf |

**Emission factors/parameters used in the agriculture sector**

| 3.A Enteric Fermentation | EF (kg $CH_4$/head/yr) | Method | Note |
|---|---|---|---|
| **3.A.1 Cattle** | | | |
| Dairy Cattle | 82.1 | T2 | Latest Inventory year figure |
| Non-Dairy Cattle | 48.0 | T2 | Latest Inventory year figure |
| **3.A.2 Sheep** | | | |
| Domestic | 5.0 | T1 | Table 10.10 |
| Merino | 6.5 | T1 | Table 10.10, value is derived as follows: (developing EF + developed EF)/2 |
| **3.A.3 Swine** | 1.0 | T1 | Table 10.10 |
| **3.A.4 Other livestock** | | | |
| Buffalo | 55.0 | T1 | Table 10.10 |
| Camels | 46.0 | T1 | Table 10.10 |
| Goats | 5.0 | T1 | Table 10.10 |
| Horses | 18.0 | T1 | Table 10.10 |
| Mules and Asses | 10.0 | T1 | Table 10.10 |
| Poultry | NA | | |

All table references given above refer to the 2006 IPCC Guidelines Volume 4 except for EFs given for cattle.

| 3.B(a) Manure Management $CH_4$ Emissions | EF (kg $CH_4$/head/yr) | Method | Note |
|---|---|---|---|
| **3.A.1 Cattle** | | | |
| Dairy Cattle | a | T1 | Table 5.14 |
| Non-Dairy Cattle | a | T1 | Table 5.14 |
| **3.A.2 Sheep** | | | |
| Domestic | b | T1 | Table 5.15 |
| Merino | b | T1 | Table 5.15 |
| **3.A.3 Swine** | a | T1 | Table 5.14 |
| **3.A.4 Other livestock** | | | |
| Buffalo | b | T1 | Table 5.15 |
| Camels | b | T1 | Table 5.15 |
| Goats | b | T1 | Table 5.15 |
| Horses | b | T1 | Table 5.15 |
| Mules and Asses | b | T1 | Table 5.15 |
| Poultry | b | T1 | Table 5.15 |

[a] Given on Table 5.14 of this Inventory Report.
[b] Given on Table 5.15 of this Inventory Report.

**Emission factors/parameters used in the agriculture sector (cont'd)**

| 3.B(b) Manure Management Direct $N_2O$ Emissions | $EF_3$ (kg $N_2O$-N / kg N excreted) | Method | Note |
|---|---|---|---|
| Liquid system | 0.005 | T1 | Table 10.21 |
| Solid storage | 0.005 | T1 | Table 10.21 |
| Dry lot | 0.02 | T1 | Table 10.21 |
| Pasture, range and paddock | - | T1 | Reported under 3.D agricultural soils category |
| Burned for fuel or as waste | - | T1 | Reported under the energy sector |
| Other (Poultry manure) | 0.001 | T1 | Table 10.21 |

All table references given above refer to the 2006 IPCC Guidelines Volume 4.

| 3.B(b) Manure Management Indirect $N_2O$ Emissions | Value | Method | Note |
|---|---|---|---|
| All related manure management systems | 0.01 | T1 | Table 11.3, $EF_4$ [kg N2O-N / (kg NH3-N + NOx-N volatilised)] |
| $Frac_{GASMS}$ | *** | T1 | ***Default values given on Table 10.22 |
| $Frac_{LEACHMS}$ | 4.5% | T1 | Mid-value between 3% and 6% given for drier climates on page 10.56 |

All value, table and page references given above refer to the 2006 IPCC Guidelines Volume 4.

| 3.C Rice Cultivation | Value | Unit | Method | Note |
|---|---|---|---|---|
| $EF_c$ | 1.30 | kg CH4 /ha/ day | T1 | Baseline emission factor for all types of water regimes, Table 5.11 |
| $SF_w$ | 1.00 | | T1 | Scaling factor for continuously flooded water regime, Table 5.12 |
| $SF_w$ | 0.60 | | T1 | Scaling factor for intermittently flooded (single aeration) water regime, Table 5.12 |
| $SF_w$ | 0.52 | | T1 | Scaling factor for intermittently flooded (multiple aeration) water regime, Table 5.12 |
| $SF_p$ | 1.00 | | T1 | Scaling factor for non-flooded pre-season less than 180 days, Table 5.13 |
| $SF_p$ | 0.68 | | T1 | Scaling factor for non-flooded pre-season more than 180 days, Table 5.13 |
| $SF_p$ | 1.90 | | T1 | Scaling factor for flooded pre-season over 30 days, Table 5.13 |

All table references given above refer to the 2006 IPCC Guidelines Volume 4.

**Emission factors/parameters used in the agriculture sector (cont'd)**

| 3.D.a Agricultural Soils Direct $N_2O$ Emissions | | EF | Method | Note |
|---|---|---|---|---|
| 3.D.a.1 | Inorganic N fertilizers | 0.01 | T1 | - |
| 3.D.a.2 | Organic N fertilizers | 0.01 | T1 | - |
| 3.D.a.3 | Urine and dung deposited by grazing animals | ** | T1 | **0.02 for cattle, buffalo, pigs, poultry and 0.01 for sheep and other animals |
| 3.D.a.4 | Crop residues | 0.01 | T1 | 0.003 is taken for flooded rice & 0.01 for crop residues except flooded rice |
| 3.D.a.5 | Loss/Gain of soil organic matter | 0.01 | T1 | Please note that this particular source category is currently reported as not occurring (NO). |
| 3.D.a.6 | Cultivation of organic soils | 8 | T1 | $EF_{2\ CG,\ Temp}$ for temperate organic crop and grassland soils |

All EF values given above refer to Table 11.1 of the 2006 IPCC Guidelines Volume 4.

| 3.D.b Agricultural Soils Indirect $N_2O$ Emissions | Value | Method | Note |
|---|---|---|---|
| $EF_4$ | 0.01 | T1 | N volatilisation and re-deposition |
| $EF_5$ | 0.0075 | T1 | Leaching/runoff |
| $Frac_{GASF}$ | 0.10 | T1 | Volatilisation from synthetic fertiliser |
| $Frac_{GASM}$ | 0.20 | T1 | Volatilisation from all organic N fertilisers applied, and dung and urine deposited by grazing animals |
| $Frac_{LEACH-(H)}$ | 0.015 | T1 | Country-specific value |

All values given above refer to Table 11.3 of the 2006 IPCC Guidelines Volume 4 except for the $Frac_{LEACH-(H)}$ value.

| 3.F Field Burning of agricultural residues | $G_{ef}$ (g /kg) | | $C_f$ | | |
|---|---|---|---|---|---|
| | $CH_4$ | $N_2O$ | $CH_4$ and $N_2O$ | Method | Note |
| 3.F.1.1 Wheat | 2.7 | 0.07 | 0.9 | T1 | |
| 3.F.1.2 Barley | 2.7 | 0.07 | 0.9 | T1 | $C_f$ value for wheat is used |
| 3.F.1.3 Maize | 2.7 | 0.07 | 0.8 | T1 | |
| 3.F.1.4 Rice | 2.7 | 0.07 | 0.8 | T1 | |

All values given above refer to Table 2.5 for $G_{ef}$ and Table 2.6 for $C_f$ of the 2006 IPCC Guidelines Volume 4.

| 3.H Urea Application | EF (tonne of C/ tonne of urea) | Method | Note |
|---|---|---|---|
| Urea fertilisation | 0.20 | T1 | Information given on page 11.32 of the 2006 IPCC Guidelines Volume 4. |

**Emission Factors Used for Waste Sector**

| | EF | AD Source |
|---|---|---|
| 5.A Solid waste disposal | Default values in 2006 IPCC Guidelines Waste Sector Table 3.1 | |
| 5.B Biological treatment of solid waste<br>5.B.1 Composting<br>5.B.1.a Municipal Solid Waste | $CH_4$: 4, $N_20$: 0.24 wet weight basis) in 2006 IPCC Guidelines | |
| 5.C Incineration and open burning of waste<br>5.C.2 Open Burning of Waste<br>5.C.2.1 Biogenic<br>5.C.2.1.a Municipal Solid Waste | $CO_2$: OF= 0.58 for MSW (Table 5.2)<br>$CH_4$ & $N_2O$: Defaults (Table 5.6) in 2006 IPCC Guidelines | TurkStat's surveys and database |
| 5.D Wastewater treatment and discharge<br>5.D.1 Domestic Wastewater | Default values (Table 6.11 & 6.3) in 2006 IPCC Guidelines<br>CS BODs for TOW calculation (Table 1) & Tij values (Table 2) | |
| 5.D.2 Industrial Wastewater | Default values (Table 6.8 & 6.9) in 2006 IPCC Guidelines | |

**Country-specific BOD values**

| BOD (g/person/day) | I |
|---|---|
| Country-specific per capita BOD for wastewater collected by sewers | Correction factor for additional industrial BOD discharged into sewers |
| 53 | 1 |

| BOD (g/person/day) | BOD (g/person/day) |
|---|---|
| Country-specific per capita BOD for receiving bodies | Country-specific per capita BOD for sludge removed |
| 25 | 28 |

| Country specific values for degrees of treatment utilization (T) by income groups | | |
|---|---|---|
| **Treatment or discharge system or pathway** | | **T (%)** |
| Rural | To sea, river and lake | 0.43 |
| | To aerobic plant, not well managed | 0.44 |
| | To septic systems | 10.72 |
| Urban | To sea, river and lake | 15.43 |
| | To aerobic plant, well managed | 44.01 |
| | To aerobic plant, not well managed | 1.82 |
| | To anaerobic digester for sludge | 20.83 |
| | To septic systems | 6.31 |
| Total | | 100 |

# Annex 4: National Energy Balance Sheets, 2018

| Distribution of Energy Supply | Hard Coal | Lignite | Asphaltite | Coke | Derivative Gases | BFG | Coke Oven Gas | BOF Gas | Coal Tar | Oil | Oil Products | Petroleum Coke |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Domestic Production (+)** | 655 | 15.122 | 770 | | | | | | | 2.994 | | |
| **Import (+)** | 23.955 | | | 523 | | | | | 3 | 22.021 | 27.529 | 3.620 |
| **Export (-)** | 51 | 0 | | 21 | | | | | 76 | | 5.095 | 348 |
| **Bunkers (-)** | | | | | | | | | | | 4.978 | |
| **Stock Change (+/-)** | 120 | -36 | -74 | 11 | | | | | -41 | 85 | -641 | -179 |
| | | | | | | | | | | | | |
| ***Primary Energy Suppley*** | **24.679** | **15.086** | **697** | **513** | **0** | **0** | **0** | **0** | **-114** | **25.099** | **16.814** | **3.093** |
| | | | | | | | | | | | | |
| ***Statistical Difference (+/-)--*** | **212** | **62** | **-35** | **70** | **0** | **0** | **0** | **0** | **4** | **0** | **356** | **410** |
| | | | | | | | | | | | | |
| **Transforation Sector** | **-18.073** | **-11.896** | **-544** | **2.786** | **430** | **51** | **343** | **35** | **141** | **-25.099** | **24.867** | **670** |
| **Electricity and Heat Production** | -13.270 | -11.645 | -544 | | -776 | -428 | -274 | -74 | | | -144 | |
| Main Activity Producer Plants | -12.153 | -11.579 | -544 | | | | | | | | -77 | |
| Autoproducers | -1.118 | -66 | | | -776 | -428 | -274 | -74 | | | -67 | |
| **Heat Production** | -219 | -250 | | | -146 | -68 | -30 | -47 | | | -85 | |
| **Coke ovens** | -4.374 | | | 2.786 | 866 | | 866 | | 141 | | | |
| **Blast Furnaces** | | | | | 1.430 | 1.242 | | 189 | | | | |
| **Petroleum Refinery** | | | | | | | | | | -24.815 | 29.569 | 670 |
| **Own use and loses** | -209 | -2 | | | -945 | -694 | -219 | -33 | | -285 | -4.473 | |
| | | | | | | | | | | | | |
| ***Total Finel Energy consumption*** | **6.606** | **3.190** | **153** | **3.299** | **430** | **51** | **343** | **35** | **27** | **0** | **41.681** | **3.763** |
| | | | | | | | | | | | | |
| ***Sectors Total*** | **6.395** | **3.129** | **188** | **3.229** | **430** | **51** | **344** | **35** | **24** | **0** | **41.325** | **3.353** |
| | | | | | | | | | | | | |
| **Industry Consumption** | **3.955** | **1.677** | **183** | **3.229** | **430** | **51** | **344** | **35** | **24** | **0** | **3.767** | **3.353** |
| **Mining and Quarrying (07,08,09)** | **0** | **1** | | **0** | | | | | | | **113** | |
| **Manufacture of Food,beverage ,tobacco products(10,11,12)** | **180** | **336** | | **42** | | | | | | | **20** | **2** |
| Manufacture of food products | 178 | 336 | | 19 | | | | | | | 16 | 2 |
| Manufacture of beverage products | | | | | | | | | | | 0 | |
| Manufacture of tobacco products | | | | | | | | | | | 0 | |
| Sugar Production (10) | 2 | 0 | | 23 | | | | | | | 3 | |
| **Manufacture of Textile and Leather Products (13,14,15)** | **103** | **502** | | | | | | | | | **4** | **0** |
| Manufacture of textile products | 83 | 450 | | | | | | | | | 2 | 0 |
| Manufacture of clothing articles | 19 | 51 | | | | | | | | | 1 | |
| Manufacture of leather and related products | 1 | | | | | | | | | | 1 | |
| **Manufacture of wood and products(16)** | **9** | **8** | | | | | | | | | **8** | |
| **Manufacture of paper and products(17,18)** | **46** | **81** | | | | | | | | | **5** | **2** |
| **Manufacture of chemical, petrochemical products(20,21,22)** | **311** | **168** | | **1** | | | | | | | **9** | |
| Manufacture of chemical products | 310 | 110 | | 0 | | | | | | | 3 | |
| Fertilizer(20) | | | | | | | | | | | 1 | |
| Manufacture of pharmaceutical products(21) | | 1 | | | | | | | | | 0 | |
| Manufacture of rubber , plastic products(22) | 0 | 58 | | 1 | | | | | | | 5 | |
| **Manufacture of non-metallic mineral products-23** | **2.006** | **557** | | | **4** | | **4** | | | | **3.431** | **3.349** |
| Manufacture of glass products(23) | | | | | | | | | | | 1 | |
| Manufacture of ceramic products(23) | 24 | 118 | | | | | | | | | 41 | 36 |
| Manufacture of cement products(23) | 1.982 | 439 | | | 4 | | 4 | | | | 3.389 | 3.313 |
| **Basic metal industry(24,25)** | **1.272** | **19** | | **3.186** | **426** | **51** | **340** | **35** | **24** | | **14** | |
| Manufacture of iron and steel products(24) | 1.264 | | | 3.145 | 426 | 51 | 340 | 35 | 24 | | 7 | |
| Manufacture of non-ferrous metal products(24) | 8 | | | 42 | | | | | | | 4 | |
| Manufacture of fabricated metal products(25) | 0 | 19 | | | | | | | | | 3 | |
| **Manufacture of Machine, Electrical, Electronic Products(26,2** | **0** | **1** | | **0** | | | | | | | **4** | |
| **Production of Transportation Equipment(29,30)** | | **2** | | | | | | | | | **5** | |
| Manufacture of Motorized Land Vehicles(29) | | | | | | | | | | | 3 | |
| Manufacture of Other Transportation Vehicles(30) | | 2 | | | | | | | | | 3 | |
| **Furniture and Other Manufacturing(31,32)** | **0** | | | | | | | | | | **1** | |
| **Construction(41,42,43)** | **26** | **1** | | | | | | | | | **39** | |
| **Other industry** | **0** | **0** | **183** | **0** | | | | | | | **114** | **0** |
| | | | | | | | | | | | | |
| **TRANSPORT** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **27.825** | **0** |
| **Rail** | | | | | | | | | | | 128 | |
| **Domestic Navigation** | | | | | | | | | | | 398 | |
| **Domestic Aviation** | | | | | | | | | | | 1.247 | |
| **Pipeline Transportation** | | | | | | | | | | | | |
| **Road** | | | | | | | | | | | 26.052 | |
| | | | | | | | | | | | | |
| **OTHER SECTORS** | **2.440** | **1.452** | **5** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **3.999** | **0** |
| **Residantial** | 1.813 | 1.186 | 5 | | | | | | | | 220 | |
| **Commercial and Public Services** | 626 | 266 | | | | | | | | | 797 | |
| **Agriculture and farming** | | | | | | | | | | | 2.981 | |
| | | | | | | | | | | | | |
| **NON ENERGY USE** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **5.735** | **0** |
| **Petrochemical feedstock** | | | | | | | | | | | **1.785** | |

| Distribution of Energy Supply | Fuel Oil | Gas Diesel Oil | Gasoline | LPG | Refinery Gas | Jet Kerosene | Kerosen | Naphta | By Products | Base Oil | White Spirit | Bitumen |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Domestic Production (+) | | | | | | | | | | | | |
| Import (+) | 2.309 | 15.263 | | 3.736 | | 513 | | 1.617 | 114 | 258 | 28 | 4 |
| Export (-) | 1.133 | 121 | 2.611 | 124 | | 116 | | 39 | 332 | 171 | 3 | 9 |
| Bunkers (-) | 875 | 93 | | | | 4.010 | | | | | | |
| Stock Change (+/-) | -42 | 102 | -61 | 16 | 2 | -236 | -16 | 2 | -23 | -23 | 4 | 37 |
| | | | | | | | | | | | | |
| **Primary Energy Suppley** | **259** | **15.151** | **-2.672** | **3.627** | **2** | **-3.850** | **-16** | **1.580** | **-241** | **64** | **29** | **33** |
| | | | | | | | | | | | | |
| **Statistical Difference (+/-)--** | **-175** | **0** | **0** | **-27** | **0** | **0** | **0** | **148** | **0** | **0** | **0** | **0** |
| | | | | | | | | | | | | |
| **Transforation Sector** | **-209** | **8.580** | **5.012** | **1.032** | **-2** | **5.097** | **24** | **352** | **503** | **219** | **5** | **2.862** |
| Electricity and Heat Production | -132 | -12 | | | | | | | | | | |
| Main Activity Producer Plants | -65 | -12 | | | | | | | | | | |
| Autoproducers | -67 | 0 | | | | | | | | | | |
| Heat Production | -85 | | | | | | | | | | | |
| Coke ovens | | | | | | | | | | | | |
| Blast Furnaces | | | | | | | | | | | | |
| Petroleum Refinery | 2.229 | 9.688 | 5.012 | 1.032 | 1.154 | 5.097 | 24 | 352 | 503 | 219 | 5 | 2.862 |
| Own use and loses | -2.221 | -1.096 | 0 | | -1.156 | | | | | | | |
| | | | | | | | | | | | | |
| **Total Finel Energy consumption** | **50** | **23.731** | **2.340** | **4.659** | **0** | **1.247** | **8** | **1.933** | **261** | **283** | **34** | **2.894** |
| | | | | | | | | | | | | |
| **Sectors Total** | **225** | **23.731** | **2.340** | **4.685** | **0** | **1.247** | **8** | **1.785** | **261** | **283** | **34** | **2.894** |
| | | | | | | | | | | | | |
| **Industry Consumption** | **27** | **255** | **4** | **128** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Mining and Quarrying (07,08,09)** | **7** | **106** | **0** | **0** | | | | | | | | |
| **Manufacture of Food,beverage ,tobacco products(10,11,12)** | **4** | **8** | **0** | **6** | | | | | | | | |
| Manufacture of food products | 1 | 7 | 0 | 6 | | | | | | | | |
| Manufacture of beverage products | 0 | 0 | | 0 | | | | | | | | |
| Manufacture of tobacco products | | 0 | | 0 | | | | | | | | |
| Sugar Production (10) | 3 | 0 | 0 | 0 | | | | | | | | |
| **Manufacture of Textile and Leather Products (13,14,15)** | **0** | **3** | **0** | **0** | | | | | | | | |
| Manufacture of textile products | 0 | 2 | 0 | 0 | | | | | | | | |
| Manufacture of clothing articles | 0 | 1 | 0 | | | | | | | | | |
| Manufacture of leather and related products | | 1 | 0 | | | | | | | | | |
| **Manufacture of wood and products(16)** | **0** | **8** | **0** | **0** | | | | | | | | |
| **Manufacture of paper and products(17,18)** | **0** | **2** | **0** | **0** | | | | | | | | |
| **Manufacture of chemical, petrochemical products(20,21,22)** | **0** | **6** | **0** | **2** | | | | | | | | |
| Manufacture of chemical products | 0 | 2 | 0 | 1 | | | | | | | | |
| Fertilizer(20) | | 1 | | | | | | | | | | |
| Manufacture of pharmaceutical products(21) | 0 | 0 | 0 | 0 | | | | | | | | |
| Manufacture of rubber , plastic products(22) | 0 | 4 | 0 | 1 | | | | | | | | |
| **Manufacture of non-metallic mineral products-23** | **14** | **67** | **0** | **1** | | | | | | | | |
| Manufacture of glass products(23) | | 0 | 0 | 0 | | | | | | | | |
| Manufacture of ceramic products(23) | | 5 | 0 | 0 | | | | | | | | |
| Manufacture of cement products(23) | 14 | 62 | | 0 | | | | | | | | |
| **Basic metal industry(24,25)** | **0** | **12** | **0** | **2** | | | | | | | | |
| Manufacture of iron and steel products(24) | 0 | 7 | 0 | 0 | | | | | | | | |
| Manufacture of non-ferrous metal products(24) | 0 | 4 | 0 | 0 | | | | | | | | |
| Manufacture of fabricated metal products(25) | 0 | 1 | 0 | 2 | | | | | | | | |
| **Manufacture of Machine, Electrical, Electronic Products(26,27,28)** | **0** | **3** | **0** | **1** | | | | | | | | |
| **Production of Transportation Equipment(29,30)** | **0** | **4** | **1** | **0** | | | | | | | | |
| Manufacture of Motorized Land Vehicles(29) | 0 | 2 | 1 | 0 | | | | | | | | |
| Manufacture of Other Transportation Vehicles(30) | 0 | 2 | 0 | 0 | | | | | | | | |
| **Furniture and Other Manufacturing(31,32)** | **0** | **1** | **0** | **1** | | | | | | | | |
| **Construction(41,42,43)** | **0** | **36** | **2** | **1** | | | | | | | | |
| **Other industry** | **0** | **0** | **0** | **114** | | | | | | | | |
| | | | | | | | | | | | | |
| **TRANSPORT** | **36** | **20.494** | **2.337** | **3.710** | **0** | **1.247** | **0** | **0** | **0** | **0** | **0** | **0** |
| Rail | | 128 | | | | | | | | | | |
| Domestic Navigation | 36 | 361 | | | | | | | | | | |
| Domestic Aviation | | | | | | 1.247 | | | | | | |
| Pipeline Transportation | | | | | | | | | | | | |
| Road | | 20.005 | 2.337 | 3.710 | | | | | | | | |
| | | | | | | | | | | | | |
| **OTHER SECTORS** | **161** | **2.981** | **0** | **848** | **0** | **0** | **8** | **0** | **0** | **0** | **0** | **0** |
| Residantial | | | | 212 | | | 8 | | | | | |
| Commercial and Public Services | 161 | | | 636 | | | | | | | | |
| Agriculture and farming | | 2.981 | | | | | | | | | | |
| | | | | | | | | | | | | |
| **NON ENERGY USE** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1.785** | **261** | **283** | **34** | **2.894** |
| **Petrochemical feedstock** | | | | | | | | **1.785** | | | | |

| Distribution of Energy Supply | Others | Natural Gas | Biofuels and Waste | Wood | Crop and Animal Residue | Biofuel | Hydro | Wind | Electricity | Other heat | Jeotermal | Solar | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Domestic Production (+) | | 359 | 3.014 | 971 | 1.883 | 159 | 5.155 | 1.716 | | | 8.343 | 1.547 | 39.675 |
| Import (+) | 68 | 41.547 | | | | | | | 213 | | | | 115.792 |
| Export (-) | 88 | 555 | | | | | | | 268 | | | | 6.067 |
| Bunkers (-) | | | | | | | | | | | | | 4.978 |
| Stock Change (+/-) | -225 | -181 | | | | | | | | | | | -756 |
| | | | | | | | | | | | | | |
| **Primary Energy Suppley** | **-245** | **41.171** | **3.014** | **971** | **1.883** | **159** | **5.155** | **1.716** | **-55** | **0** | **8.343** | **1.547** | **143.666** |
| | | | | | | | | | | | | | |
| **Statistical Difference (+/-)--** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **668** |
| | | | | | | | | | | | | | |
| **Transforation Sector** | **722** | **-16.934** | **-465** | **0** | **-465** | **0** | **-5.155** | **-1.716** | **21.823** | **2.378** | **-6.389** | **-671** | **-34.517** |
| Electricity and Heat Production | | -15.031 | -437 | | -437 | | -5.155 | -1.716 | 26.213 | 994 | -6.389 | -671 | -28.569 |
| Main Activity Producer Plants | | -12.989 | -411 | | -411 | | -5.062 | -1.708 | 24.500 | 485 | -6.389 | -544 | -26.470 |
| Autoproducers | | -2.042 | -26 | | -26 | | -92 | -8 | 1.713 | 509 | | -127 | -2.099 |
| Heat Production | | -1.113 | -28 | | -28 | | | | | 1.813 | | | -28 |
| Coke ovens | | | | | | | | | | | | | -581 |
| Blast Furnaces | | | | | | | | | | | | | 1.430 |
| Petroleum Refinery | 722 | -753 | | | | | | | -150 | -429 | | | 3.422 |
| Own use and loses | | -37 | | | | | | | -4.240 | | | | -10.192 |
| | | | | | | | | | | | | | |
| **Total Finel Energy consumption** | **477** | **24.237** | **2.548** | **971** | **1.418** | **159** | **0** | **0** | **21.768** | **2.378** | **1.954** | **877** | **109.149** |
| | | | | | | | | | | | | | |
| **Sectors Total** | **477** | **24.237** | **2.548** | **971** | **1.418** | **159** | **0** | **0** | **21.768** | **2.378** | **1.954** | **877** | **108.481** |
| | | | | | | | | | | | | | |
| **Industry Consumption** | **0** | **9.434** | **834** | **0** | **834** | **0** | **0** | **0** | **10.095** | **2.343** | **0** | **307** | **36.277** |
| **Mining and Quarrying (07,08,09)** | | **128** | | | | | | | **123** | **1** | | | **367** |
| **Manufacture of Food,beverage ,tobacco products(10,11,12)** | | **1.106** | **169** | | **169** | | | | **659** | **455** | | | **2.968** |
| Manufacture of food products | | 1.005 | 169 | | 169 | | | | 539 | 455 | | | 2.718 |
| Manufacture of beverage products | | 25 | | | | | | | 49 | | | | 74 |
| Manufacture of tobacco products | | 26 | | | | | | | 16 | | | | 43 |
| Sugar Production (10) | | 50 | | | | | | | 55 | | | | 134 |
| **Manufacture of Textile and Leather Products (13,14,15)** | | **1.005** | | | | | | | **1.499** | **87** | | | **3.199** |
| Manufacture of textile products | | 908 | | | | | | | 1.266 | 87 | | | 2.797 |
| Manufacture of clothing articles | | 89 | | | | | | | 187 | | | | 348 |
| Manufacture of leather and related products | | 7 | | | | | | | 46 | | | | 55 |
| **Manufacture of wood and products(16)** | | **63** | **181** | | **181** | | | | **205** | **66** | | | **540** |
| **Manufacture of paper and products(17,18)** | | **177** | **9** | | **9** | | | | **309** | **176** | | | **803** |
| **Manufacture of chemical, petrochemical products(20,21,22)** | | **2.155** | **28** | | **28** | | | | **1.096** | **228** | | | **3.996** |
| Manufacture of chemical products | | 1.296 | 2 | | 2 | | | | 458 | 210 | | | 2.389 |
| Fertilizer(20) | | 694 | | | | | | | 35 | | | | 729 |
| Manufacture of pharmaceutical products(21) | | 52 | | | | | | | 47 | | | | 100 |
| Manufacture of rubber , plastic products(22) | | 113 | 26 | | 26 | | | | 556 | 18 | | | 778 |
| **Manufacture of non-metallic mineral products-23** | | **1.703** | **374** | | **374** | | | | **1.141** | **59** | | | **9.274** |
| Manufacture of glass products(23) | | 642 | | | | | | | 191 | | | | 834 |
| Manufacture of ceramic products(23) | | 885 | 11 | | 11 | | | | 201 | | | | 1.280 |
| Manufacture of cement products(23) | | 176 | 362 | | 362 | | | | 749 | 59 | | | 7.160 |
| **Basic metal industry(24,25)** | | **1.536** | **64** | | **64** | | | | **2.786** | **262** | | | **9.591** |
| Manufacture of iron and steel products(24) | | 1.171 | 44 | | 44 | | | | 2.247 | 216 | | | 8.544 |
| Manufacture of non-ferrous metal products(24) | | 248 | 1 | | 1 | | | | 331 | 47 | | | 680 |
| Manufacture of fabricated metal products(25) | | 117 | 19 | | 19 | | | | 209 | | | | 367 |
| **Manufacture of Machine, Electrical, Electronic Products(26,27,28** | | **98** | **3** | | **3** | | | | **254** | **6** | | | **367** |
| **Production of Transportation Equipment(29,30)** | | **182** | **5** | | **5** | | | | **232** | **7** | | | **434** |
| Manufacture of Motorized Land Vehicles(29) | | 175 | 2 | | 2 | | | | 192 | 7 | | | 379 |
| Manufacture of Other Transportation Vehicles(30) | | 7 | 4 | | 4 | | | | 40 | | | | 55 |
| **Furniture and Other Manufacturing(31,32)** | | **28** | | | | | | | **75** | | | | **104** |
| **Construction(41,42,43)** | | **538** | | | | | | | **328** | **0** | | | **932** |
| **Other industry** | | **717** | | | | | | | **1.387** | **995** | | **307** | **3.702** |
| | | | | | | | | | | | | | |
| **TRANSPORT** | **0** | **355** | **159** | **0** | **0** | **159** | **0** | **0** | **114** | **0** | **0** | **0** | **28.452** |
| Rail | | | | | | | | | 87 | | | | 215 |
| Domestic Navigation | | | | | | | | | | | | | 398 |
| Domestic Aviation | | | | | | | | | | | | | 1.247 |
| Pipeline Transportation | | 279 | | | | | | | 27 | | | | 306 |
| Road | | 76 | 159 | | | 159 | | | | | | | 26.287 |
| | | | | | | | | | | | | | |
| **OTHER SECTORS** | **0** | **13.887** | **1.555** | **971** | **584** | **0** | **0** | **0** | **11.559** | **35** | **1.954** | **570** | **37.455** |
| Residantial | | 10.416 | 1.555 | 971 | 584 | | | | 4.778 | | 853 | 570 | 21.396 |
| Commercial and Public Services | | 3.296 | | | | | | | 6.182 | 35 | 475 | | 11.678 |
| Agriculture and farming | | 174 | | | | | | | 599 | | 627 | | 4.381 |
| | | | | | | | | | | | | | |
| **NON ENERGY USE** | **477** | **561** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **6.296** |
| **Petrochemical feedstock** | | | | | | | | | | | | | **1.785** |

Energy balance sheets for 1972-2018 are available on the MENR website (https://www.eigm.gov.tr/tr-TR/Denge-Tablolari/Denge-Tablolari).

# Annex 5: Completeness

**Table A8.1 Completeness, Sources and sinks not estimated ("NE")**

| GHG | Sector(2) | Source/sink category(2) |
|---|---|---|
| CH4 | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.b Solid Fuel Transformation |
| CH4 | LULUCF | 4.C Grassland/4.C.1 Grassland Remaining Grassland/4(V) Biomass Burning/Wildfires |
| CH4 | LULUCF | 4.C Grassland/4.C.2 Land Converted to Grassland/4(V) Biomass Burning/Wildfires |
| CO2 | Agriculture | 3.G Liming/3.G.1 Limestone CaCO3 |
| CO2 | Agriculture | 3.G Liming/3.G.2 Dolomite CaMg(CO3)2 |
| CO2 | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.a Coal Mining and Handling/1.B.1.a.1 Underground Mines/1.B.1.a.1.i Mining Activities |
| CO2 | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.a Coal Mining and Handling/1.B.1.a.1 Underground Mines/1.B.1.a.1.ii Post-Mining Activities |
| CO2 | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.a Coal Mining and Handling/1.B.1.a.1 Underground Mines/1.B.1.a.1.iii Abandoned Underground Mines |
| CO2 | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.a Coal Mining and Handling/1.B.1.a.2 Surface Mines/1.B.1.a.2.i Mining Activities |
| CO2 | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.a Coal Mining and Handling/1.B.1.a.2 Surface Mines/1.B.1.a.2.ii Post-Mining Activities |
| CO2 | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.b Solid Fuel Transformation |
| CO2 | Energy | 1.C CO2 Transport and Storage/Injection and Storage/Injection |
| CO2 | LULUCF | |
| CO2 | LULUCF | 4.C Grassland/4.C.1 Grassland Remaining Grassland/4(V) Biomass Burning/Wildfires |
| CO2 | LULUCF | 4.C Grassland/4.C.2 Land Converted to Grassland/4(V) Biomass Burning/Wildfires |
| N2O | Agriculture | 3.1 Livestock/3.B Manure Management/3.B.2 N2O and NMVOC Emissions/3.B.2.5 Indirect N2O Emissions |
| N2O | Energy | 1.B Fugitive Emissions from Fuels/1.B.1 Solid Fuels/1.B.1.b Solid Fuel Transformation |
| N2O | Industrial Processes and Product Use | 2.G Other Product Manufacture and Use/2.G.3 N2O from Product Uses/2.G.3.a Medical Applications |
| N2O | LULUCF | 4.C Grassland/4.C.1 Grassland Remaining Grassland/4(V) Biomass Burning/Wildfires |
| N2O | LULUCF | 4.C Grassland/4.C.2 Land Converted to Grassland/4(V) Biomass Burning/Wildfires |

**Table A8.2 Completeness, Sources and sinks reported elsewhere ("IE")**

| | Source/sink category | Explanation |
|---|---|---|
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Biomass | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Diesel Oil | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Gasoline | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Liquefied Petroleum Gases (LPG) | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Gasoline | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Biomass 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Diesel Oil 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses/Biomass | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses/Diesel Oil 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses | Included under "1.A.3.e Other Transportation" |

**Table A8.2 Completeness, Sources and sinks reported elsewhere ("IE")(Cont'd)**

| | Source/sink category | Explanation |
|---|---|---|
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Gasoline | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Biomass<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Diesel Oil<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles | Included under "1.A.3.e Other Transportation" |
| CH4 | 1.AA Fuel Combustion - Sectoral approach/1.A.4 Other Sectors/1.A.4.c Agriculture/Forestry/Fishing/1.A.4.c.iii Fishing<br>1.AA Fuel Combustion - Sectoral approach/1.A.4 Other Sectors/1.A.4.c Agriculture/Forestry/Fishing/1.A.4.c.iii Fishing/Gas/Diesel Oil | Included under 1.A.4.c.i |
| CH4 | 4.B Cropland/4.B.1 Cropland Remaining Cropland/4(V) Biomass Burning/Wildfires | Report in "agriculture sector" |
| CH4 | 4.B Cropland/4.B.2 Land Converted to Cropland/4(V) Biomass Burning/Wildfires | Report in "agriculture sector" |
| CH4 | 4.E Settlements/4.E.1 Settlements Remaining Settlements | included in "agriculture sector" |
| CH4 | 4.F Other Land/4.F.2 Land Converted to Other Land | included in "agriculture sector" |
| CH4 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.1 Biogenic/5.C.1.1.b Other (please specify)/Clinical Waste | Emissions from 5.C.1.1.b Clinical Waste are included in 1.A.1.a |
| CH4 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.1 Biogenic/5.C.1.1.b Other (please specify)/Industrial Solid Wastes | Emissions from 5.C.1.1.b Industrial Solid Wastes are included in 1.A.1.a, 1.A.2.c and 1.A.2.g |
| CH4 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.2 Non-biogenic/5.C.1.2.b Other (please specify)/Clinical Waste | Emissions from 5.C.1.2.b Clinical Waste are included in 1.A.1.a |
| CH4 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.2 Non-biogenic/5.C.1.2.b Other (please specify)/Industrial Solid Wastes | Emissions from 5.C.1.2.b Industrial Solid Wastes are included in 1.A.1.a, 1.A.2.c and 1.A.2.g |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Biomass | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Diesel Oil | Included under "1.A.3.e Other Transportation" |

**Table A8.2 Completeness, Sources and sinks reported elsewhere ("IE")(Cont'd)**

| | Source/sink category | Explanation |
|---|---|---|
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Gasoline | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Liquefied Petroleum Gases (LPG) | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Gasoline | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Biomass<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Diesel Oil<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses/Biomass<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses/Diesel Oil<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Gasoline | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Biomass<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles | Included under "1.A.3.e Other Transportation" |

**Table A8.2 Completeness, Sources and sinks reported elsewhere ("IE")(Cont'd)**

| | Source/sink category | Explanation |
|---|---|---|
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Diesel Oil<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles | Included under "1.A.3.e Other Transportation" |
| CO2 | 1.AA Fuel Combustion - Sectoral approach/1.A.4 Other Sectors/1.A.4.c Agriculture/Forestry/Fishing/1.A.4.c.iii Fishing<br>1.AA Fuel Combustion - Sectoral approach/1.A.4 Other Sectors/1.A.4.c Agriculture/Forestry/Fishing/1.A.4.c.iii Fishing/Gas/Diesel Oil | Included under 1.A.4.c.i |
| CO2 | 1.AD Feedstocks, reductants and other non-energy use of fuels/Liquid Fuels/Lubricants | Included under 2D |
| CO2 | 2.C Metal Industry/2.C.1 Iron and Steel Production/2.C.1.b Pig Iron | CO2 emissions from pig iron production is included in emissions from steel production |
| CO2 | 4.B Cropland/4.B.1 Cropland Remaining Cropland/4(V) Biomass Burning/Wildfires | Report in "agriculture sector" |
| CO2 | 4.B Cropland/4.B.2 Land Converted to Cropland/4(V) Biomass Burning/Wildfires | Report in "agriculture sector" |
| CO2 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.1 Biogenic/5.C.1.1.b Other (please specify)/Clinical Waste | Emissions from 5.C.1.1.b Clinical Waste are included in 1.A.1.a |
| CO2 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.1 Biogenic/5.C.1.1.b Other (please specify)/Industrial Solid Wastes | Emissions from 5.C.1.1.b Industrial Solid Wastes are included in 1.A.1.a, 1.A.2.c and 1.A.2.g |
| CO2 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.2 Non-biogenic/5.C.1.2.b Other (please specify)/Clinical Waste | Emissions from 5.C.1.2.b Clinical Waste are included in 1.A.1.a |
| CO2 | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.2 Non-biogenic/5.C.1.2.b Other (please specify)/Industrial Solid Wastes | Emissions from 5.C.1.2.b Industrial Solid Wastes are included in 1.A.1.a, 1.A.2.c and 1.A.2.g |
| HFC-134a | 2.F Product Uses as Substitutes for ODS/2.F.6 Other Applications/2.F.6.a Emissive/HFC-134a | All emissions caused by HFC-134a is given in this section due to lack of disaggregated data. Emission estimates are made by tier 1 and default emission factor. |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Biomass | Included under "1.A.3.e Other Transportation" |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Diesel Oil | Included under "1.A.3.e Other Transportation" |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.i Cars/Liquefied Petroleum Gases (LPG) | Included under "1.A.3.e Other Transportation" |

**Table A8.2 Completeness, Sources and sinks reported elsewhere ("IE")(Cont'd)**

| | Source/sink category | Explanation |
|---|---|---|
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Gasoline | Included under "1.A.3.e Other Transportation" |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks/Biomass<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.ii Light duty trucks | Included under "1.A.3.e Other Transportation" |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iii Heavy duty trucks and buses/Biomass | Included under "1.A.3.e Other Transportation" |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Gasoline | Included under "1.A.3.e Other Transportation" |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles/Biomass<br>1.AA Fuel Combustion - Sectoral approach/1.A.3 Transport/1.A.3.b Road Transportation/1.A.3.b.iv Motorcycles | Included under "1.A.3.e Other Transportation" |
| N2O | 1.AA Fuel Combustion - Sectoral approach/1.A.4 Other Sectors/1.A.4.c Agriculture/Forestry/Fishing/1.A.4.c.iii Fishing<br>1.AA Fuel Combustion - Sectoral approach/1.A.4 Other Sectors/1.A.4.c Agriculture/Forestry/Fishing/1.A.4.c.iii Fishing/Gas/Diesel Oil | Included under 1.A.4.c.i |
| N2O | 4(IV) Indirect N2O Emissions from Managed Soils/Atmospheric Deposition | i.e. included in "agriculture" |
| N2O | 4.A Forest Land/4.A.1 Forest Land Remaining Forest Land/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Inorganic N Fertilizers | Direct N2O Emissions from N Inputs to Managed Soils in Forest Land is included in the Agriculture Sector |
| N2O | 4.A Forest Land/4.A.1 Forest Land Remaining Forest Land/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Organic N Fertilizers | Direct N2O Emissions from N Inputs to Managed Soils in Forest Land is included in the Agriculture Sector |
| N2O | 4.A Forest Land/4.A.2 Land Converted to Forest Land/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Inorganic N Fertilizers | Direct N2O Emissions from N Inputs to Managed Soils in Forest Land is included in the Agriculture Sector |
| N2O | 4.A Forest Land/4.A.2 Land Converted to Forest Land/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Organic N Fertilizers | Direct N2O Emissions from N Inputs to Managed Soils in Forest Land is included in the Agriculture Sector |
| N2O | 4.B Cropland/4.B.1 Cropland Remaining Cropland/4(V) Biomass Burning/Wildfires | Report in "agriculture sector" |

**Table A8.2 Completeness, Sources and sinks reported elsewhere ("IE")(Cont'd)**

| | Source/sink category | Explanation |
|---|---|---|
| N2O | 4.B Cropland/4.B.2 Land Converted to Cropland/4(V) Biomass Burning/Wildfires | Report in "agriculture sector" |
| N2O | 4.E Settlements/4.E.1 Settlements Remaining Settlements/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Inorganic N Fertilizers | i.e. included in "agriculture sector" |
| N2O | 4.E Settlements/4.E.1 Settlements Remaining Settlements/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Organic N Fertilizers | i.e. included in "agriculture sector" |
| N2O | 4.E Settlements/4.E.2 Land Converted to Settlements/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Inorganic N Fertilizers | i.e. included in "agriculture sector" |
| N2O | 4.E Settlements/4.E.2 Land Converted to Settlements/4(I) Direct N2O Emissions from N Inputs to Managed Soils/Organic N Fertilizers | i.e. included in "agriculture sector" |
| N2O | 4.F Other Land/4.F.2 Land Converted to Other Land | included in "agriculture sector" |
| N2O | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.1 Biogenic/5.C.1.1.b Other (please specify)/Clinical Waste | Emissions from 5.C.1.1.b Clinical Waste are included in 1.A.1.a |
| N2O | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.1 Biogenic/5.C.1.1.b Other (please specify)/Industrial Solid Wastes | Emissions from 5.C.1.1.b Industrial Solid Wastes are included in 1.A.1.a, 1.A.2.c and 1.A.2.g |
| N2O | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.2 Non-biogenic/5.C.1.2.b Other (please specify)/Clinical Waste | Emissions from 5.C.1.2.b Clinical Waste are included in 1.A.1.a |
| N2O | 5.C Incineration and Open Burning of Waste/5.C.1 Waste Incineration/5.C.1.2 Non-biogenic/5.C.1.2.b Other (please specify)/Industrial Solid Wastes | Emissions from 5.C.1.2.b Industrial Solid Wastes are included in 1.A.1.a, 1.A.2.c and 1.A.2.g |
| N2O | 5.D Wastewater Treatment and Discharge/5.D.2 Industrial Wastewater | Emissions from 5.D.2 are included in 5.D.1 |
| SF6 | 2.G Other Product Manufacture and Use/2.G.1 Electrical Equipment/SF6 | Due to lack of data, NE is entered |

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