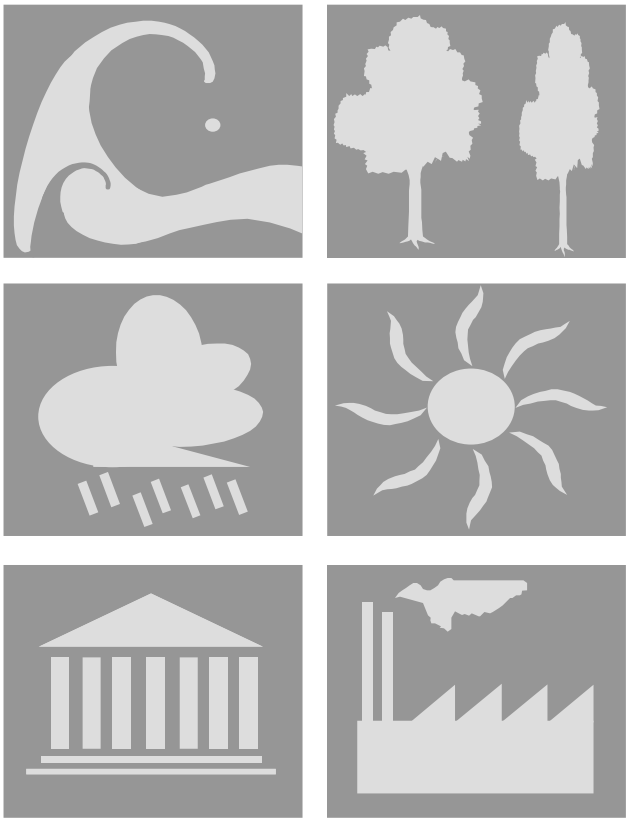
HELLENIC REPUBLIC
MINISTRY OF ENVIRONMENT
AND ENERGY

CLIMATE CHANGE



EMISSIONS INVENTORY

NATIONAL INVENTORY REPORT OF GREECE FOR GREENHOUSE AND OTHER GASES FOR THE YEARS 1990-2023

NATIONAL INVENTORY DOCUMENT

April 2025

EXECUTIVE SUMMARY

ES.1 Greenhouse gas inventories and climate change

The present report, prepared by Greece contains estimates of GHG emissions for the period 1990-2023. The methodologies applied for the estimation of GHG emissions are discussed and the activity data and emission factors used are presented. This report was prepared by the Ministry of Environment and Energy (MEEN), with the external consultancy assistance of the National Technical University of Athens (School of Chemical Engineering).

Greenhouse gas emissions inventories

Annual inventories of greenhouse and other gases emissions form an essential element of each national environmental policy-making process. They can be used to derive information on emissions trends, with reference to a pre-selected base year, and can assist in monitoring the progress of existing abatement measures for the reduction of greenhouse gases emissions.

The quality of greenhouse gas (GHG) inventories relies on the integrity of the methodologies used, the completeness of reporting, and the procedures for compilation of data. To this end, the Conference of the Parties (COP) has developed standardized requirements for reporting national inventories.

According to Decision 18/CMA.1, Parties are required to submit their GHG inventory covering emissions and removals of direct GHGs (carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3) from five sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry (LULUCF); and waste), and for all years from the base year (or period) to two years before the inventory is due.

Institutional arrangements and inventory preparation

The **Ministry of Environment and Energy, MEEN**, is the governmental body responsible for the development and implementation of environmental policy in Greece, as well as for the provision of information concerning the state of the environment in Greece in compliance with relevant requirements defined in international conventions, protocols and agreements. Moreover, the MEEN is responsible for the co-ordination of all involved ministries, as well as any relevant public or private organization, in relation to the implementation of the provisions of the UNFCCC, Kyoto Protocol and the Paris Agreement.

In this context, the MEEN has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission (contact persons: Artemis Gryllia, a.gryllia@prv.ypeka.gr, Charikleia Chranioti, ch.chranioti@prv.ypeka.gr, Christina Pavlopoulou, ch.pavlopoulou@prv.ypeka.gr, Address: Patission 47, 11251 Athens, Greece, tel.: +30210 8665938).

The entities participating in it are:

- The **Division of Climate Change and Air Quality of MEEN** designated as the national entity responsible for the national inventory, which keeps the overall responsibility, but also plays an active role in the inventory planning, preparation and management.

- The preparation of the annual inventory for all sectors has been assigned to **National Technical University of Athens (NTUA) / School of Chemical Engineering**, on a contract basis by MEEN.

- **Governmental ministries and agencies** through their appointed focal persons, ensure the data provision.

International or national associations, along with individual public or private industrial companies contribute to data providing and development of methodological issues as appropriate.

The preparation of the Greek GHG emissions inventory is based on the application of the 2006 IPCC Guidelines.

The compilation of the inventory is completed in three main stages:

Stage 1: The first stage consists of data collection and check for all source/sink categories. The main data sources used are the Hellenic Statistical Authority, the national energy balance, the government ministries/agencies involved and large private enterprises, along with the verified reports from installations under the EU ETS.

Quality control of activity data includes the comparison of the same or similar data from alternative data sources (e.g. Hellenic Statistical Authority and ETS reports) as well as time-series assessment in order to identify changes that cannot be explained. In cases where problems and/or inconsistencies are identified, the agency's representative, responsible for data providing, is called to explain the inconsistency and/or help solving the problem.

Stage 2: Once the reliability of input data is checked and certified, emissions/removals per source/sink category are estimated. Emissions estimates are then transformed to the format required by the CRT Reporter. This stage also includes the evaluation of the emission factors used and the assessment of the consistency of the methodologies applied in relation to the provisions of the 2006 IPCC Guidelines.

Quality control checks, when at this stage, are related to time-series assessment as well as to the identification and correction of any errors / gaps while estimating emissions / removals and filling in the CRT Reporter.

Stage 3: The last stage involves the compilation of the NIR and its internal (i.e. within technical consultant) check. The official approval procedure follows for one month period of interactions between the technical consultant (NTUA) and the Division of Climate Change and Air Quality of MEEN, starting on the 1st of February of the year of

submission. During this period, the technical consultant has to revise the report according to the observations and recommendations of the competent authority. On the basis of this interaction process, the final version of the report is compiled. The Division of Climate Change and Air Quality submits the NIR to the European Commission and to the UNFCCC Secretariat.

The information that is related to the annual GHG emissions inventory is kept at the Centralized Inventory File.

ES.2 Emissions trends for aggregated greenhouse gas emissions

The GHG emissions trends (CO_2, CH_4, N_2O, HFC, PFC and SF_6) for the period 1990 – 2023 are presented in ***Table ES.1*** (in kt CO_2 eq).

It is noted that according to the IPCC Guidelines, emissions estimates for international marine and aviation bunkers were not included in the national totals, however they are reported separately as memo items.

UNFCCC base year GHG emissions for Greece (year 1990) were estimated at 101.72 Mt CO2 eq (without LULUCF) and 103.99 Mt CO2 eq with LULUCF.

In 2023, GHG emissions (without LULUCF) amounted to 71.93 Mt CO2 eq showing a decrease of 30.82% compared to 1990 levels. If emissions / removals from LULUCF were to be included, then the decrease would be 33.31%

Carbon dioxide emissions accounted for 72.27% of total GHG emissions in 2023 (without LULUCF) and decreased by 37.69% from 1990 (41.66% with LULUCF). Methane emissions accounted for 16.20% of total GHG emissions in 2023 (without LULUCF) and decreased by 7.0% from 1990, while nitrous oxide emissions accounted for 5.16% of the total GHG emissions in 2023 and decreased by 45.85% from 1990. Finally, f-gases emissions (from production and consumption) that accounted for 6.24% of total GHG emissions in 2023 were increased by 29.21% from 1995.

Table ES.1 Total GHG emissions in Greece (in kt CO2 eq) for the period 1990-2023

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
A. GHG emissions per gas (excluding LULUCF)															
CO_2	83,438.04	83,407.50	84,975.66	84,284.96	86,430.25	86,963.21	89,114.95	93,801.54	98,621.80	97,934.81	102,973.18	105,361.88	105,000.51	109,066.72	109,485.27
CH_4	12,526.76	12,513.86	12,588.60	12,639.37	12,714.45	12,913.16	13,093.12	13,041.52	13,279.69	13,237.92	13,244.44	12,469.73	12,565.28	12,680.96	12,707.31
N_2O	6,855.77	6,736.87	6,588.65	6,095.98	5,973.97	6,157.05	6,308.90	6,166.36	6,091.67	6,047.55	5,867.17	5,740.05	5,694.40	5,624.06	5,628.87
HFC	991.01	1,173.04	962.74	1,702.86	2,272.32	3,487.68	4,046.99	4,344.36	4,856.97	5,667.03	4,460.65	4,079.50	4,375.21	4,112.54	4,309.68
PFC	171.09	171.93	168.83	101.56	63.23	56.52	48.32	113.00	139.86	94.78	110.09	75.81	79.64	80.61	79.37
SF_6	3.02	3.11	3.21	3.30	3.39	3.53	3.62	3.67	3.71	3.81	3.92	4.00	4.18	4.18	4.39
Total	**103,985.69**	**104,006.32**	**105,287.68**	**104,828.03**	**107,457.62**	**109,581.14**	**112,615.89**	**117,470.44**	**122,993.71**	**122,985.88**	**126,659.44**	**127,730.96**	**127,719.22**	**131,569.08**	**132,214.90**
B. GHG emissions/removals from LULUCF															
CO_2	-2,355.55	-2,451.33	-2,716.68	-3,190.93	-2,922.76	-3,135.14	-2,436.97	-2,271.58	-2,414.96	-2,765.71	-2,780.33	-2,689.55	-3,007.06	-2,761.21	-2,750.41
CH_4 in kt	2.51	1.24	3.67	3.28	3.06	1.74	1.05	2.31	6.31	0.48	8.32	1.12	0.15	0.21	0.54
N_2O in kt	0.02	0.02	0.04	0.04	0.04	0.03	0.03	0.04	0.07	0.03	0.09	0.04	0.04	0.04	0.05
Total	**-2,279.61**	**-2,412.13**	**-2,604.37**	**-3,089.61**	**-2,827.54**	**-3,078.82**	**-2,400.45**	**-2,196.63**	**-2,220.27**	**-2,744.08**	**-2,523.73**	**-2,646.56**	**-2,992.17**	**-2,743.79**	**-2,722.39**
C. GHG Emissions from International Transport															
CO_2	14,136.62	14,932.09	15,294.12	15,460.88	15,753.14	16,084.99	16,535.05	17,236.86	18,998.77	19,311.12	18,364.24	19,227.92	19,553.34	20,628.46	21,024.82
CH_4 in kt	123.66	124.88	123.58	124.92	124.62	125.99	126.47	128.78	133.36	136.92	137.72	141.31	139.52	138.49	139.75
N_2O in kt	242.36	255.57	272.47	298.66	318.79	329.67	324.14	350.38	418.17	429.38	308.58	343.43	341.55	337.60	349.19
Total	**14,502.64**	**15,312.54**	**15,690.17**	**15,884.46**	**16,196.55**	**16,540.64**	**16,985.66**	**17,716.01**	**19,550.30**	**19,877.42**	**18,810.54**	**19,712.66**	**20,034.41**	**21,104.54**	**21,513.76**

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
A. GHG emissions per gas (excluding LULUCF)																			
CO_2	113,888.96	112,419.55	114,545.69	111,080.35	104,319.84	97,354.14	94,505.22	91,392.59	81,713.25	78,635.69	74,926.67	71,359.61	74,841.75	71,778.09	65,736.32	55,576.93	57,527.91	57,609.05	51,988.22
CH_4	12,798.54	12,882.80	12,777.13	12,643.73	12,251.93	12,505.24	12,344.49	12,170.19	11,904.56	11,697.28	11,486.37	11,113.80	11,462.64	11,621.66	11,389.49	11,380.26	11,750.50	11,769.10	11,650.25
N_2O	5,467.73	5,311.31	5,399.06	5,184.78	4,860.91	5,035.28	4,821.51	4,441.49	4,171.65	3,972.23	3,904.74	3,952.14	4,016.62	3,924.41	3,914.53	3,961.99	3,942.88	3,741.15	3,712.24
HFC	4,503.29	2,568.97	3,058.38	3,494.70	3,805.73	4,215.53	4,480.25	4,864.48	5,403.54	5,505.32	5,641.71	5,844.57	5,806.45	5,559.42	5,137.08	4,816.27	4,675.61	4,558.17	4,491.83
PFC	82.70	78.87	93.29	107.64	82.83	117.35	100.08	133.83	156.13	121.65	108.05	122.05	113.58	122.07	123.63	133.54	111.18	87.37	87.07
SF_6	6.35	8.23	9.75	7.40	5.17	6.04	5.29	5.20	5.31	5.07	5.22	5.36	5.16	5.09	5.07	5.09	5.03	5.03	5.05
Total	**136,747.56**	**133,269.72**	**135,883.30**	**132,518.61**	**125,326.40**	**119,233.58**	**116,256.84**	**113,007.78**	**103,354.44**	**99,937.24**	**96,072.75**	**92,397.52**	**96,246.21**	**93,010.74**	**86,306.12**	**75,874.08**	**78,013.11**	**77,769.87**	**71,934.67**
B. GHG emissions/removals from LULUCF																			
CO_2	-3,576.62	-3,651.81	-2,577.83	-3,409.08	-3,509.49	-3,444.94	-3,555.50	-3,626.28	-2,590.28	-2,031.84	-3,498.27	-4,101.31	-3,836.82	-4,680.12	-5,187.96	-5,182.56	-5,224.13	-5,259.76	-4,677.36
CH_4 in kt	0.42	0.84	12.85	1.74	1.85	0.66	0.71	1.75	0.64	0.38	0.43	1.27	0.74	0.78	3.11	0.75	5.49	2.22	19.05
N_2O in kt	0.05	0.06	0.14	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.07	0.05	0.09	0.06	0.15
Total	**-3,551.69**	**-3,613.71**	**-2,180.56**	**-3,342.41**	**-3,439.29**	**-3,410.99**	**-3,520.49**	**-3,560.11**	**-2,557.62**	**-2,007.41**	**-3,472.35**	**-4,050.74**	**-3,802.04**	**-4,644.11**	**-5,082.41**	**-5,147.27**	**-5,046.51**	**-5,180.49**	**-4,103.01**
C. GHG Emissions from International Transport																			
CO_2	21,333.01	22,004.63	22,639.51	21,938.64	24,796.63	22,045.52	19,771.67	16,465.15	16,246.67	16,267.32	16,801.61	17,129.16	16,901.36	17,129.03	17,540.52	15,096.29	16,478.75	16,478.75	21,333.01
CH_4 in kt	136.69	134.34	128.34	120.41	114.73	121.33	105.59	79.91	89.94	88.07	89.35	81.69	82.22	79.59	77.87	66.06	72.16	72.16	72.16
N_2O in kt	351.01	374.27	363.07	355.02	319.70	280.80	216.54	178.59	165.97	176.04	191.34	207.55	211.29	216.27	218.73	178.57	200.81	465.81	730.81
Total	**21,820.72**	**22,513.24**	**23,130.92**	**22,414.08**	**25,231.06**	**22,447.65**	**20,093.80**	**16,723.65**	**16,502.58**	**16,531.42**	**17,082.30**	**17,418.41**	**17,194.88**	**17,424.89**	**17,837.12**	**15,340.92**	**16,751.72**	**17,016.72**	**17,281.72**

1) Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals
2) *Land Use, Land Use Change and Forestry* is not included

ES.3 Emissions trends per sector

GHG emissions trends by sector for the period 1990 – 2023 are presented in ***Table ES.2***.

Emissions from Energy in 2023 accounted for 67.63% of total GHG emissions (without LULUCF) and decreased by approximately 36.93% compared to 1990 levels.

The living standards improvement, due to the economic growth, the important growth of the services sector and the introduction of natural gas in the Greek energy system represent the basic factors affecting emissions trends from Energy for the period 1990 – 2007. A reduction of emissions is observed by 41.9% in 2019 compared to 2008, due to the economic recession at the beginning of the period, but also due to measures as the increase of RES and NG share of the energy mixture, along with energy efficiency improvement actions. In addition, the high decrease in 2020 compared to 2019 is mainly attributed to the significant reduction of the operation of lignite-fired plants, which were replaced by higher share of NG and renewables compared to previous years, and the COVID-19 restrictions in transport sector. According to the NECP of Greece, there is an undergoing plan for the phasing-out of all but one lignite-plants by 2023. The remaining plant will be converted to NG by 2028. GHG emissions have increased by 5.5% in 2022 compared to 2020, which is attributed to the removal of COVID-19 confinement measures, but decreased by 10.7% in 2023 compared to 2022.

The living standards improvement resulted in an increase of energy consumption and particularly electricity consumption (mainly in the residential – tertiary sector), passenger cars ownership and transportation activity. The increase of electricity consumption led not only to the increase of direct emissions (due to combustion for electricity generation) but also of fugitive methane emissions from lignite mining. At the same time total CO2 emissions per electricity produced have decreased mainly as a result of the introduction of natural gas and RES into the electricity system. It should be mentioned that the availability of hydropower has a significant effect to emissions trends. For instance, the significant increase of electricity demand in 1999 was not followed by a similar increase of emissions because of the penetration of natural gas and the high availability of hydropower. It should be also mentioned that up to 1996 supply of natural gas was exclusively minor quantities from domestic primary production. In essence, the introduction of natural gas in the Greek energy system started in 1997 and since then its consumption has been continuously increasing.

The majority of GHG emissions (43.1%) in 2023 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 36.1%, 8.9% and 10.4% respectively. The rest 0.8% and 0.7% of total GHG emissions from Energy derived from fugitive emissions from fuels and other (mobile).

Within the fuel combustion activities, the only sector with increased emissions compared to 1990 is transport, showing an increase of 20.92%. It should be noted that GHG emissions from transport were reduced by 14% in 2020 compared to 2019 at a significant share due to COVID-19 restrictions. Emissions from manufacturing industries and construction, energy industries and other sectors (i.e. residential, tertiary and agriculture sectors) had decreased by around 53.75%, 51.55% and 41.26%, respectively, compared to 1990. The decrease in the other sectors (i.e. residential,

tertiary and agriculture sectors) is noticeable during the recent years, with the exception of 2020 compared to 2019, where the increase of emissions is attributed to a significant share to the COVID-19 restrictions in transport. Finally, fugitive emissions from fuels decreased by 71.10% for the period 1990 – 2023, due to the reduction of the use of lignite for power production.

Emissions from Industrial Processes and Product use in 2023 accounted for 12.67% of the total emissions (excluding LULUCF) and decreased by 16.64% compared to 1990 levels. Emissions from IPPU are characterized by intense fluctuations during the period 1990 – 2023 reaching a minimum value of 9.11 Mt CO2 eq in 2023 and a maximum value of 15.25 Mt CO2 eq in 1999. The low value for 2023 is directly related to the fact that many industries have ceased their operation, whereas the maximum value is attributed to changes in industrial production and especially in HCFC-22 production. It should be noted that had it not been for the consumption of f-gases subcategory, the decrease of the recent years would have been much deeper.

Emissions from Agriculture, that accounted for 11.08% of total emissions in 2023 (without LULUCF), decreased by approximately 24.35% compared to 1990 levels. Emissions reduction is mainly due to the reduction of N2O emissions from agricultural soils, because of the reduction in the use of synthetic nitrogen fertilizers and animal population. The decrease in the use of synthetic nitrogen fertilizers is attributed to the increase of organic farming, the high price of fertilizers and the impact of initiatives to promote good practice in fertilizer use. The changes of the rest determining parameters of GHG emissions from the sector (e.g. crops production etc.) have a minor effect on GHG emissions trend.

Emissions from the Waste Sector (8.62% of the total emissions, without LULUCF), increased by approximately 15.15% from 1990. Living standards improvement resulted in an increase of the generated waste and thus of emissions since 1990. However, the increase of recycling along with the exploitation of the biogas produced limits the increase of methane emissions. At the same time, emissions from wastewater handling have considerably decreased, due to the continuous increase of the population served by aerobic wastewater handling facilities.

The Land Use, Land-Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2023. The sink capacity of the LULUCF sector fluctuates between -2 Mt CO2 eq. and -5.18 Mt CO2 eq., showing fluctuations in trend. This is the result of the increase of the sink capacity of the Forest Land, Grassland and Cropland category.

Table ES.2a Total GHG emissions (in kt CO_2 eq) by sector for the period 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy	77,133.43	77,246.16	79,228.42	78,870.98	81,109.57	81,174.63	83,395.36	87,928.58	92,652.89	92,091.99	96,890.77	99,346.16	99,208.74	103,085.36	103,538.52
IPPU	10,933.61	10,855.35	10,322.46	10,642.69	11,130.89	12,818.42	13,470.98	13,908.39	14,550.68	15,245.64	14,281.94	13,797.22	13,972.53	13,832.46	13,989.37
Agriculture	10,534.68	10,548.85	10,271.49	9,791.13	9,524.15	9,887.56	9,938.03	9,865.49	9,822.21	9,734.57	9,563.76	9,536.74	9,537.18	9,512.85	9,541.09
Waste	5,383.97	5,355.96	5,465.31	5,523.23	5,693.00	5,700.53	5,811.52	5,767.99	5,967.92	5,913.69	5,922.97	5,050.84	5,000.78	5,138.40	5,145.92
Total (1)	**103,985.69**	**104,006.32**	**105,287.68**	**104,828.03**	**107,457.62**	**109,581.14**	**112,615.89**	**117,470.44**	**122,993.71**	**122,985.88**	**126,659.44**	**127,730.96**	**127,719.22**	**131,569.08**	**132,214.90**
LULUCF	**-2,279.61**	**-2,412.13**	**-2,604.37**	**-3,089.61**	**-2,827.54**	**-3,078.82**	**-2,400.45**	**-2,196.63**	**-2,220.27**	**-2,744.08**	**-2,523.73**	**-2,646.56**	**-2,992.17**	**-2,743.79**	**-2,722.39**
Index per sector															
Energy	100.00	100.15	102.72	102.25	105.15	105.24	108.12	114.00	120.12	119.39	125.61	128.80	128.62	133.65	134.23
IPPU	100.00	99.28	94.41	97.34	101.80	117.24	123.21	127.21	133.08	139.44	130.62	126.19	127.79	126.51	127.95
Agriculture	100.00	100.13	97.50	92.94	90.41	93.86	94.34	93.65	93.24	92.40	90.78	90.53	90.53	90.30	90.57
Waste	100.00	99.48	101.51	102.59	105.74	105.88	107.94	107.13	110.85	109.84	110.01	93.81	92.88	95.44	95.58
Total (2)	**100.00**	**100.02**	**101.25**	**100.81**	**103.34**	**105.38**	**108.30**	**112.97**	**118.28**	**118.27**	**121.80**	**122.84**	**122.82**	**126.53**	**127.15**

1) Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

2) *Land Use, Land Use Change and Forestry* is not included

Table ES.2b Total GHG emissions (in kt CO2 eq) by sector for the period 2005-2023

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Energy	107,379.67	106,056.84	108,314.44	105,412.56	100,450.70	93,261.20	92,161.13	88,474.05	78,070.49	74,616.79	71,299.97	67,043.04	70,348.04	67,389.30	61,298.69	51,598.40	53,552.06	54,453.19	48,650.80
IPPU	14,774.64	12,522.30	12,924.61	12,712.27	10,977.42	11,433.82	10,044.06	10,855.73	11,571.53	11,937.56	11,579.42	12,087.35	12,382.11	11,991.49	11,344.36	10,170.87	9,997.43	9,126.21	9,114.57
Agriculture	9,337.32	9,244.70	9,368.95	9,092.01	8,881.73	9,198.69	8,965.32	8,839.48	8,754.65	8,347.14	8,165.96	8,157.39	8,189.34	8,121.04	8,100.53	8,421.27	8,356.22	7,976.39	7,969.54
Waste	5,255.93	5,445.89	5,275.30	5,301.77	5,016.55	5,339.87	5,086.33	4,838.53	4,957.77	5,035.75	5,027.39	5,109.74	5,326.72	5,508.91	5,562.53	5,683.54	6,107.40	6,214.07	6,199.77
Total (1)	**136,747.56**	**133,269.72**	**135,883.30**	**132,518.61**	**125,326.40**	**119,233.58**	**116,256.84**	**113,007.78**	**103,354.44**	**99,937.24**	**96,072.75**	**92,397.52**	**96,246.21**	**93,010.74**	**86,306.12**	**75,874.08**	**78,013.11**	**77,769.87**	**71,934.67**
LULUCF	**-3,551.69**	**-3,613.71**	**-2,180.56**	**-3,342.41**	**-3,439.29**	**-3,410.99**	**-3,520.49**	**-3,560.11**	**-2,557.62**	**-2,007.41**	**-3,472.35**	**-4,050.74**	**-3,802.04**	**-4,644.11**	**-5,082.41**	**-5,147.27**	**-5,046.51**	**-5,180.49**	**-4,103.01**
Index per sector																			
Energy	139.21	137.50	140.42	136.66	130.23	120.91	119.48	114.70	101.21	96.74	92.44	86.92	91.20	87.37	79.47	66.89	69.43	70.60	63.07
IPPU	135.13	114.53	118.21	116.27	100.40	104.58	91.86	99.29	105.83	109.18	105.91	110.55	113.25	109.68	103.76	93.02	91.44	83.47	83.36
Agriculture	88.63	87.75	88.93	86.31	84.31	87.32	85.10	83.91	83.10	79.23	77.52	77.43	77.74	77.09	76.89	79.94	79.32	75.72	75.65
Waste	97.62	101.15	97.98	98.47	93.18	99.18	94.47	89.87	92.08	93.53	93.38	94.91	98.94	102.32	103.32	105.56	113.44	115.42	115.15
Total (2)	**131.51**	**128.16**	**130.68**	**127.44**	**120.52**	**114.66**	**111.80**	**108.68**	**99.39**	**96.11**	**92.39**	**88.86**	**92.56**	**89.45**	**83.00**	**72.97**	**75.02**	**74.79**	**69.18**

1) Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

2) *Land Use, Land Use Change and Forestry* is not included

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1. National circumstances, institutional arrangements and cross-cutting information

1.1 Background information on GHG inventories and climate change

The impact of all human activities on the climate of earth has been recognized as the greatest global environmental challenge involving the whole international community. The mitigation of the effects of this problem requires responses from governments, economic sectors and all societal actors working together.

Naturally occurring greenhouse gases (GHG) include water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). In the last years, a new category of greenhouse gases has emerged that includes hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF_6) and nitrogen fluoride (NF3). These gases are man-made and are mainly used in a number of industrial activities in replacement of CFCs. Other naturally occurring gases, which do not contribute directly to the greenhouse effect, are carbon monoxide (CO), oxides of nitrogen (NOx), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2).

1.1.1 Background information on climate change

United Nations Framework Convention on Climate Change

In response to the emerging evidence that climate change could have a major global impact, the United Nations Framework Convention on Climate Change (henceforth the Convention) was adopted on 9 May 1992 and was opened for signature in Rio de Janeiro in June 1992. Greece signed the Convention in Rio and ratified it in 1994 (Law 2205/94).

The ultimate objective of the Convention is the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Convention recognizes that the developed countries should take the lead in combating climate change and calls these countries to:

- Adopt policies and measures to mitigate climate change.
- Return, individually or jointly, to 1990 levels of carbon dioxide and other greenhouse gas by the year 2000.
- Provide technology transfer and financial resources to help developing countries so as to confront climate change impacts and to develop, ensuring at the same time the environmental protection through the restraint of GHG emissions.

Paris Agreement

The Paris Agreement builds upon the Convention and – for the first time – brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort.

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives. The Agreement also provides for enhanced transparency of action and support through a more robust transparency framework.

The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and on their implementation efforts.

The EU and its Member States were committed to a binding target of an at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990, to be fulfilled jointly, as set out in the conclusions by the European Council of October 2014. In December 2020, as part of the European Green Deal EU leaders have agreed on a more ambitious goal for cutting greenhouse gases - reducing them by 55% by 2030, rather than 40%. The European Climate Law writes into law the goal set out in the European Green Deal for Europe's economy and society to become climate-neutral by 2050. The law also sets the intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

1.1.2 Background information on greenhouse gas inventories

The objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to stabilize greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent and reduce dangerous human-induced interference with the climate system. The ability of the international community to achieve this objective is dependent on an accurate knowledge of GHG emissions trends, and on our collective ability to alter these trends.

In accordance with Articles 4 and 12 of the Convention and the relevant decisions of the Conference of the Parties (COP), Annex I Parties to the Convention submit to the secretariat national greenhouse gas inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. These inventories are subject to an

annual technical review process. In addition, Annex I Parties provide inventory data in summary form in their national communications and biennial reports under the Convention.

Annual inventories of greenhouse and other gases emissions form an essential element of each national environmental policy-making process. They can be used to derive information on emissions trends, with reference to a pre-selected base year, and can assist in monitoring the progress of existing abatement measures for the reduction of greenhouse gases emissions.

The quality of greenhouse gas (GHG) inventories relies on the integrity of the methodologies used, the completeness of reporting, and the procedures for compilation of data. To this end, the Conference of the Parties (COP) has developed standardized requirements for reporting national inventories.

According to Decision 18/CMA.1, Parties are required to submit their GHG inventory covering emissions and removals of direct GHGs (carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3)) from five sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry (LULUCF); and waste), and for all years from the base year (or period) to two years before the inventory is due.

The National Inventory Report comprises a national inventory document and CRTs for the electronic reporting of information specified in the MPGs (chapter II of annex to 18/CMA.1). Therefore, the inventory submissions are in two parts:

1. Common Reporting Tables (CRT) tables – a series of standardized data tables containing mainly quantitative information.

2. National Inventory Document (NID) – a report containing transparent and detailed information on the inventory. It should include descriptions of the methodologies used in the estimations (including references and sources of information), the data sources, the institutional arrangements for the preparation of the inventory (including quality assurance and control procedures), and recalculations and changes compared with the previous inventory.

Good annual inventories should include transparent documentation and data to enable the reader to understand the underlying assumptions and calculations of the reported emission estimates. Parties should implement and maintain national inventory arrangements for the estimation of anthropogenic GHG emissions by sources and removals by sinks. The national inventory arrangements include all institutional, legal and procedural arrangements made within a Party for estimating emissions and removals of GHGs, and for reporting and archiving inventory information.

Greece has to comply with the above-mentioned reporting requirements. Parallel commitments also exist under the European Union Regulation No 2018/1999 and its implementing acts, on the Governance of the Energy Union and Climate Action.

1.1.3 Structure of the report

The present NIR consists of 13 chapters and 5 annexes. **Chapter 1** contains (a) a presentation of the institutional, legal and procedural arrangements for inventory planning and preparation, (b) a brief description of basic methodological issues and (c) an overview of the completeness of the inventory.

Indirect CO2 from the atmospheric oxidation of CH4, CO and NMVOCs and indirect N2O emissions from other than the agriculture and LULUCF sources have not been estimated and included in the inventory. Therefore, no Chapter related to "Indirect CO2 and nitrous oxide emissions was included in the NIR.

There is no NF3 use in Greece. Therefore, **NF3 emissions** does not occur in Greece. This is also reported by the appropriate notation keys in the CRT Tables.

Emissions trends (including other gases) per gas and per sector for the period 1990 – 2021 are discussed in **Chapter 2**, while comprehensive information regarding methodologies used for the estimation of GHG emissions per source category are presented in **Chapters 3 – 7**. In **Chapter 8** an overview of the recalculations made since the 2022 submission and the future improvements planned is presented.

As concerns the annexes, in **Annex I** the methodology for the determination of key categories is described, while in **Annexes II** and **III** the methodology for the estimate of carbon dioxide emissions from the energy sector is discussed (sectoral and reference approach respectively). The calculations made for the assessment of uncertainty are presented in **Annex IV**.

1.2 A description of national circumstances and institutional arrangements

1.2.1 Overview of institutional, legal and procedural arrangements for compiling GHG inventory

The **Ministry of Environment and Energy, MEEN**, is the governmental body responsible for the development and implementation of environmental policy in Greece, as well as for the provision of information concerning the state of the environment in Greece in compliance with relevant requirements defined in international conventions, protocols and agreements. Moreover, the MEEN is responsible for the co-ordination of all involved ministries, as well as any relevant public or private organization, in relation to the implementation of the provisions of the UNFCCC, Kyoto Protocol and the Paris Agreement.

In this context, the MEEN has the overall responsibility for the national GHG inventory, and the official consideration and approval of the inventory prior to its submission (contact persons: Artemis Gryllia, a.gryllia@prv.ypeka.gr, Charikleia (Chara) Chranioti ch.chranioti@prv.ypeka.gr, Christina Pavlopoulou, ch.pavlopoulou@prv.ypeka.gr, Address: Patission 47, 11251 Athens, Greece, tel.: +30210 8665938).

Figure 1.1 provides an overview of the organizational structure of the National Inventory System. The entities participating in it are:

- The **Division of Climate Change and Air Quality of MEEN** designated as the national entity responsible for the national inventory, which keeps the overall responsibility, but also plays an active role in the inventory planning, preparation and management.

- The preparation of the annual inventory for all sectors has been assigned to **National Technical University of Athens (NTUA) / School of Chemical Engineering**, on a contract basis by MEEN.

- **Other Ministries and Governmental Agencies** through their appointed focal persons, ensure the data provision.

International or national associations, along with individual public or private industrial companies contribute to data providing and development of methodological issues as appropriate.

The legal framework defining the roles-responsibilities and the co-operation between the MEEN Climate team, the Inventory team and the designated contact points of the competent Ministries was formalized by the Joint Ministerial Decision 22993/2017 (OG B' 1710) entitled "Structure and operation of the National Greenhouse Gases Inventory System". The above-mentioned decision defines the competent authority and its responsibilities concerning the inventory preparation, data providing or other relative information. This formal framework establishes an Interministerial Technical Working Group for the collaboration between the entities involved, assuring the timely

collection and quality of the activity data required and solving data access restriction problems raised due to confidentiality issues.

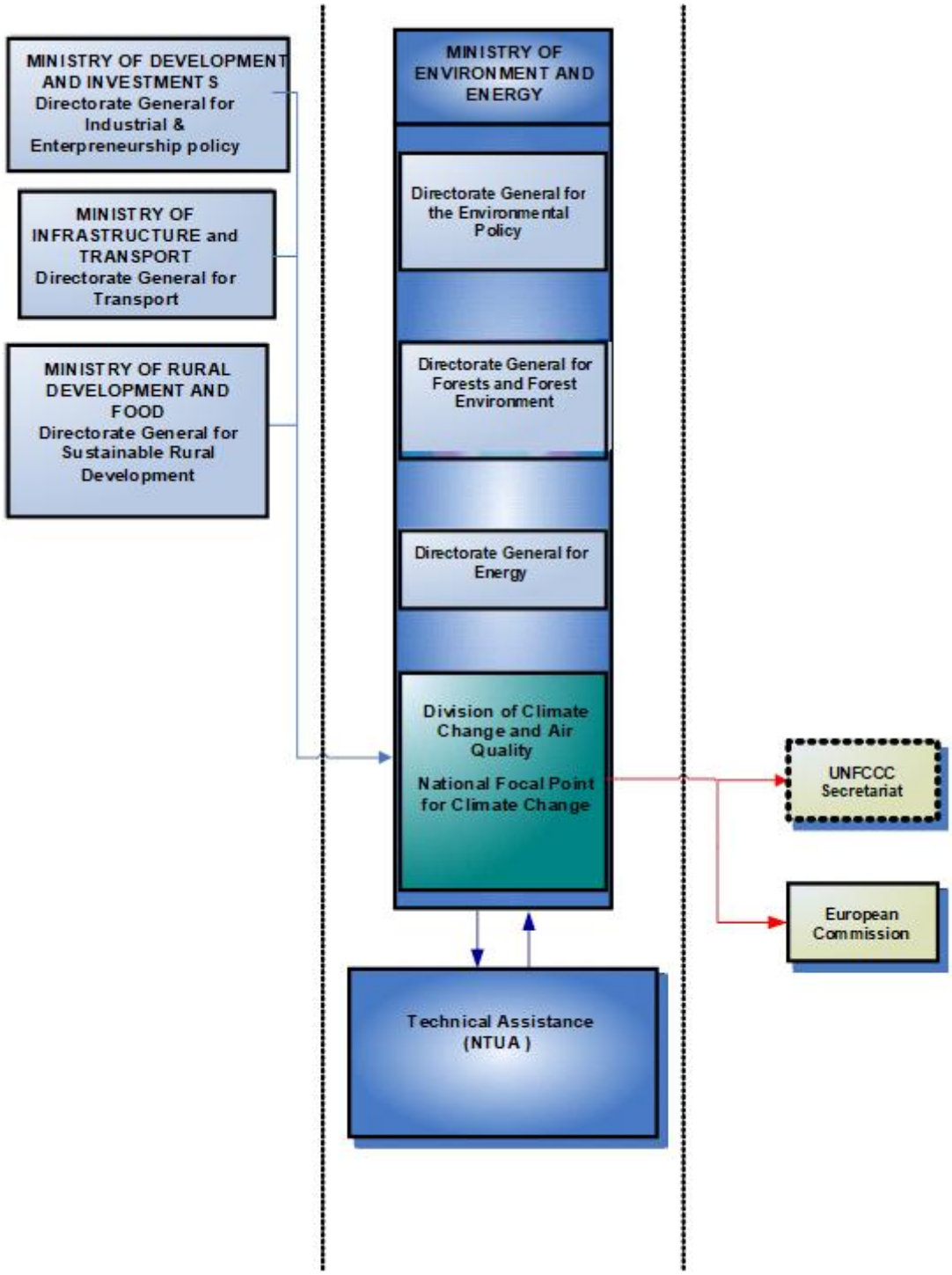

Figure 1.1 Organizational Structure of the National Inventory System

1.2.2 Roles and Responsibilities

1.2.2.1 Ministry of Environment and Energy

The Ministry of Environment and Energy, MEEN, has the overall responsibility, as the national entity, for the national GHG inventory. Among its responsibilities are the following:

- ✓ The co-ordination of all ministries and governmental agencies involved, as well as any relevant public or private organization. In this context, it oversees the operation of the National System and decides on the necessary arrangements to ensure compliance with relevant decisions of the COP and the COP/CMP.
- ✓ The supervising of the inventory compiling procedure and the official submission of all reports and inventories.
- ✓ The response to any issues raised by the inventory review process under Article 8 of the Kyoto Protocol, in co-operation with the technical consultant (NTUA), who has the technical and scientific responsibility for the inventory planning, preparation and management of the inventory, as mentioned above.
- ✓ The timely submission of the GHG inventory to the European Commission and to the UNFCCC Secretariat.
- ✓ The keeping of the Centralised Inventory File, which is delivered to the inventory team which has the technical responsibility for the inventory planning, preparation and management (currently NTUA) at the beginning of each inventory cycle. The Centralised Inventory File is kept at the premises of the MEEN.
- ✓ The administration of the National Registry. Greece cooperates with the Member States of the European Union and with the supplementary transaction log and the registry of the European Community by maintaining the national registries in a consolidated system. The supervision of Quality Assurance/Quality Control Plan (QA/QC)

As it appears from the above description, the role of the MEEN is not narrowed to the co-ordination of the entities involved in the inventory process and the facilitation of the activity data transfer from the data providers to the Technical Assistant (NTUA). The MEEN has an active role in monitoring and overseeing the inventory process through continuous communication and frequent scheduled and / or ad-hoc meetings with the Technical Assistant (NTUA) and the competent Ministries or other Agencies involved.

1.2.2.2 Technical Assistance

The Ministry of Environment and Energy has assigned, on a contract basis, the National Technical University of Athens (NTUA) / School of Chemical Engineering as the national institution that has the technical and scientific responsibility for the planning, preparation and management of the annual national inventory for all sectors. In this framework, the NTUA has the following responsibilities / tasks to fulfil for the GHG inventory preparation:

1. Data collection (activity data and emission factors) for all source categories that are Energy, Industrial Processes, Solvents and Other Product Use, Agriculture, Waste and LULUCF).

2. Reliability check of input data through

3. the comparison of the same or similar data from alternative data sources and

4. time-series assessment in order to identify changes that cannot be explained.

5. Selection of the appropriate methodologies according to the 2006 IPCC guidelines, preparation of GHG emissions estimates by applying the methodologies and models having been selected.

6. Data processing and archiving.

7. Assessment of the consistency of the methodologies applied, inventory improvement – recalculations.

8. Reliability check of results.

9. Key categories analysis.

10. Uncertainty assessment.

11. Preparation of Common Reporting Format (CRT) tables.

12. Preparation of National Inventory Report (NIR).

13. Reporting of the required information according to European Regulations.

14. Preparation and keeping of annual Centralised Inventory File. At the end of each cycle of the inventory preparation, all inventory related information is handled by the MEEN's employees responsible for keeping the Centralised Inventory File (member of the Climate Team), who in turn gives the latest version of all relevant files to the NTUA at the beginning of the next inventory cycle.

15. Development of QA/QC procedures.

16. Implementing the QA/QC procedures under the supervision of MEEN.

17. Training the representatives of data providing agencies on inventory issues.

The NTUA co-operates with a number of government agencies and other entities for the preparation of the inventory (see next section). It should be mentioned that this co-operation is not restricted to data collection but it also concerns methodological issues as appropriate. However, the technical consultant (NTUA) are responsible for the final decision concerning methodological issues.

The names and contact details of the NTUA inventory team follows:

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   Scientific responsible - coordinator
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It should be mentioned that, whenever necessary, the above mentioned NTUA's Inventory Team is ad hoc supported by experts either from the NTUA or other institutions.

1.2.2.3 Ministries/ Government agencies

The following government agencies and Ministries, develop and maintain, within their competencies, data sets and emission methodology information necessary for the estimation of GHG emissions / removals. Most of these institutes have been used as sources of data since the first submission of Greek GHG national inventory. However, new sources of information are being sought both for further inventory development and improvement (higher Tier methodology usage) and quality control issues.

The co-operation with the following government agencies and other entities for the preparation of the inventory is indispensable, as those agencies and entities develop and maintain statistical data necessary for the estimation of GHG emissions / removals.

Each of the following Ministries/agencies, has appointed focal persons responsible for data provision:

- The Ministry of Environment and Energy provides:
  - annual data for energy consumption and production
  - data for solid waste management and wastewater treatment
  - activity data and emissions for the installations included in the Emissions Trading system
  - data for f-gases use
  - data for emissions / removals from LULUCF activities.
- The Ministry of Development and Investments provides industry data.
- The Ministry of Rural Development and Food provides information and data (through the Hellenic Statistical Authority which processes primary data collected by the Ministry) for the main indices and parameters of rural economy (e.g. animal population, cultivated areas, crops production, etc.).
- The Ministry of Infrastructure and Transport provides information and data for the vehicle fleet and its technical characteristics. The Civil Aviation Organization, supervised by the same Ministry provides information on Landing and Take-off cycles for both domestic and international aviation.

- The Hellenic Statistical Authority represents the main source of information for the estimation of emissions / removals from most of the IPCC source / sink categories.

Data are also obtained from International Organizations as the United Nations Food and Agricultural Organization (FAO), the EUROSTAT, the International Iron and Steel Institute, the International Energy Association. These data are supplementary to the data collected from the aforementioned data providers.

Furthermore, other government organisations, associations, and individual public and private industrial companies contribute to data providing and development of methodological issues as appropriate. For example, data is provided from the National Oganization for Medicines, while data from the Association of Motor Vehicles Importers Representatives or the Hellenic Association of Fertilizer professionals and traders are supplementary to the official data and are used in cases where official data are temporarily not available. Individual industrial companies / installations, either public or private, as Power Public Corporation, cement plants etc., constitute an additional data source for the GHG inventory preparation. However, these data are used as supplementary to the official data (e.g. for QC).

1.3 Inventory planning and preparation

1.3.1 GHG inventory, data collection, processing and storage

The preparation of the Greek GHG emissions inventory is based on the application of the 2006 IPCC Guidelines.

The compilation of the inventory is completed in three main stages (***Figure 1.2***), while the timetable for the completion of those stages in the annual inventory cycle is presented in ***Figure 1.3.***

Stage 1: The first stage consists of data collection and check for all source/sink categories. The main data sources used are the Hellenic Statistical Authority, the national energy balance, the government Ministries / Governmental Agencies involved and large private enterprises, along with the verified reports from installations under the EU ETS.

Quality control of activity data include the comparison of the same or similar data from alternative data sources (e.g. Hellenic Statistical Authority and ETS reports) as well as time-series assessment in order to identify changes that cannot be explained. In cases where problems and/or inconsistencies are identified, the agency's representative, responsible for data providing, is called to explain the inconsistency and/or help solving the problem.

Stage 2: Once the reliability of input data is checked and certified, emissions/removals per source/sink category are estimated. Emissions estimates are then transformed to the format required by the CRT Reporter. This stage also includes the evaluation of the emission factors used and the assessment of the consistency of the methodologies applied in relation to the provisions of the 2006 IPCC Guidelines.

Quality control checks, when at this stage, are related to time-series assessment as well as to the identification and correction of any errors / gaps while estimating emissions / removals and filling in the CRT Reporter.

Stage 3: The last stage involves the compilation of the NIR and its internal (i.e. within technical consultant) check. The official approval procedure follows for one-month period of interactions between the technical consultant (NTUA) and the Division of Climate Change and Air Quality of MEEN, starting on the 1st of February of the year of submission. During this period, the technical consultant has to revise the report according to the observations and recommendations of the competent authority. On the basis of this interaction process, the final version of the report is compiled. The Division of Climate Change and Air Quality submits the NIR to the European Commission and to the UNFCCC Secretariat.

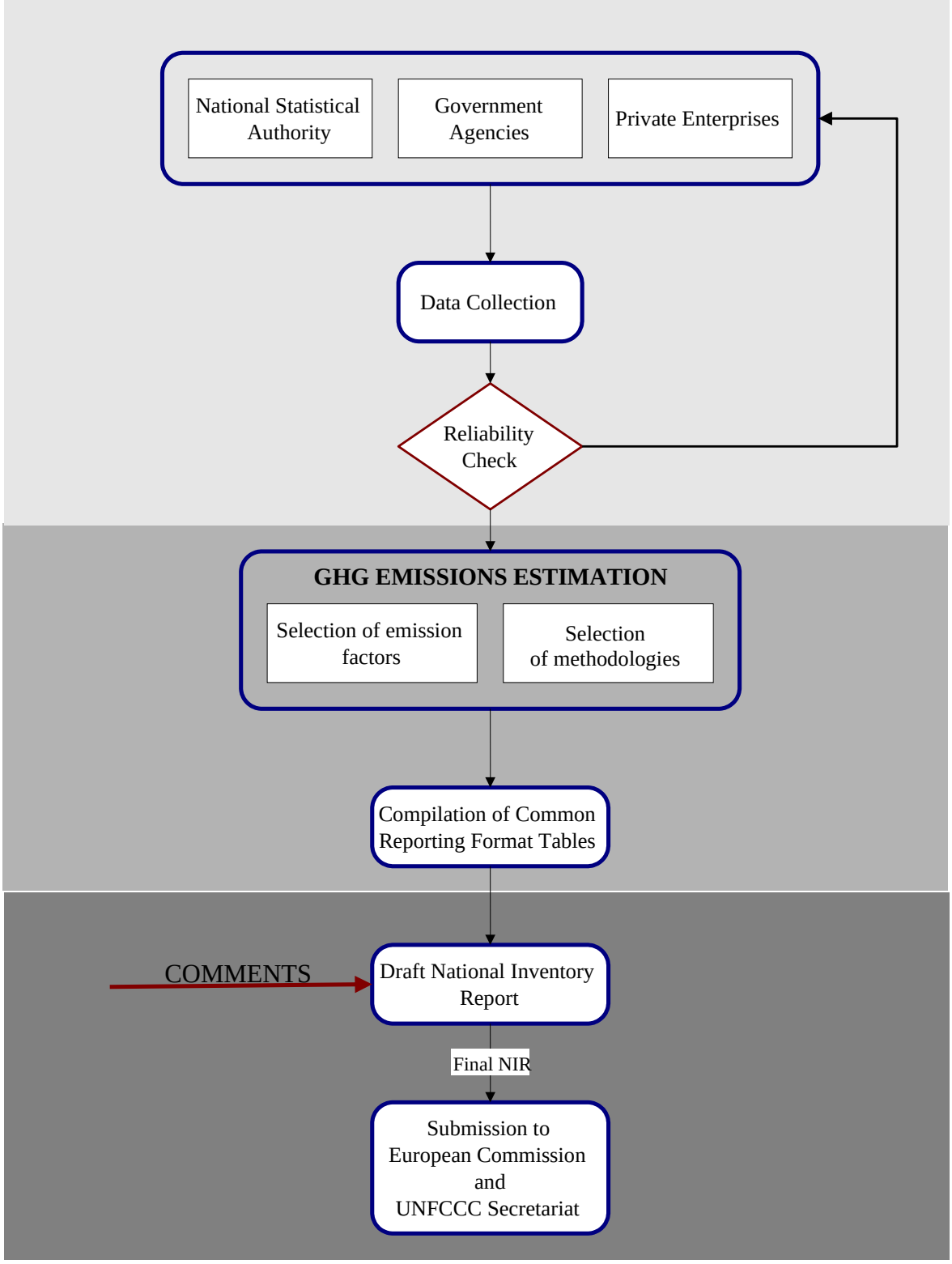


Figure 1.2 GHG emissions inventory preparation process in Greece

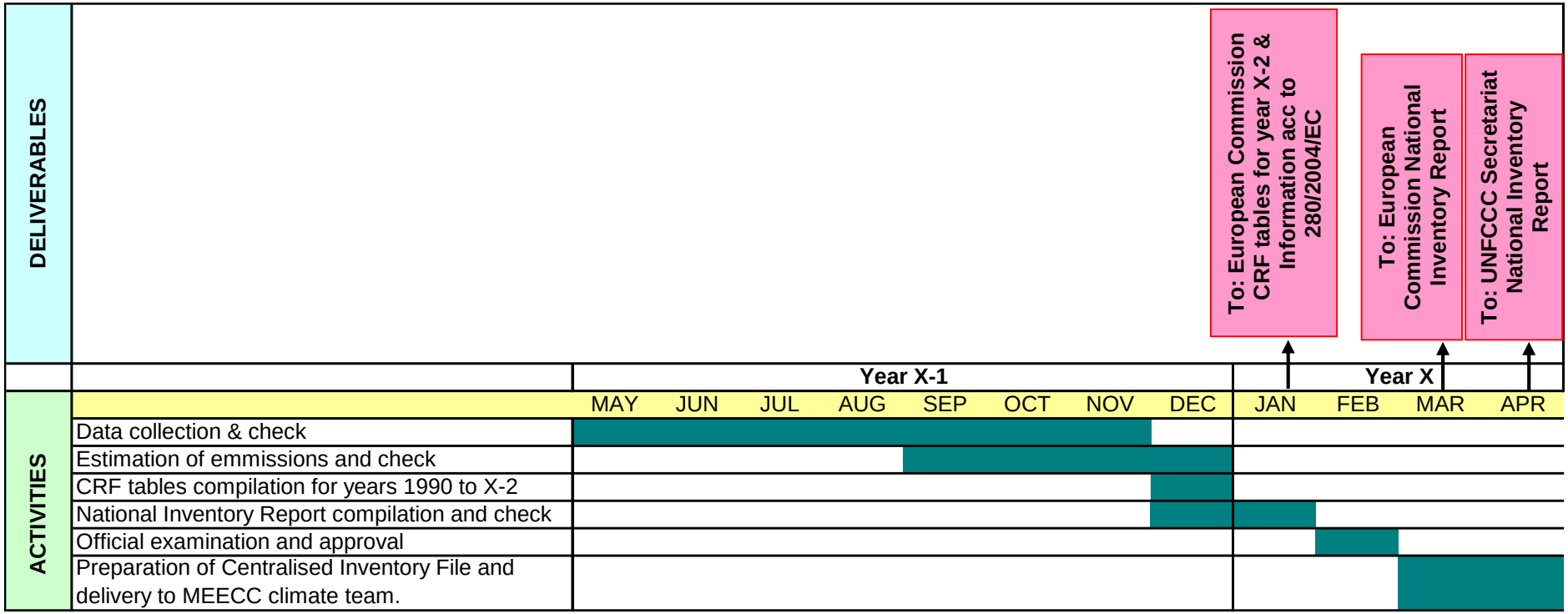


Figure 1.3 Timetable for the preparation and submission of GHG emissions/removals inventory in Greece

As shown in the timetable, the government ministries and agencies and the individual private or public industrial companies referred previously should have collected and delivered to the MEEN Climate Team and the technical consultant (NTUA) the respective activity data needed for the inventory (for year X-2) and any changes in activity data for the period 1990 to year X-2, within the time period of May to November of year X-1 (X is the submission year of CRT tables and NIR referred to X-2 GHG emissions inventory).

The information that is related to the annual GHG emissions inventory (activity data, emission factors, analytic results, compilation in the required analysis level of the CRT tables) is stored in MS Excel spreadsheets. Moreover, the final results (NIR and CRT tables) are available in the MEEN web site (https://ypen.gov.gr/perivallon/klimatiki-allagi/ektheseis-kai-yfistameni-katastasi/etisies-ethnikes-apografes-aerion-tou-thermokipiouatth-apo-to-2005/).

In addition, and within the context of the Quality Assurance/Quality Control system developed, two master files have been organized aiming at the systematic and safe archiving of inventory information: the Input Data File and the Centralised Inventory File.

- The Input Data File contains (in electronic format and/or hard copy) all input data and parameters that are necessary for the estimation of GHG emissions/removals. Data are stored in files by sector and reference year.
- The Centralised Inventory File includes all information relevant to the GHG emissions/removals inventory. At the end of each cycle of the inventory preparation, all inventory related information is handled by NTUA to the person responsible for keeping the Centralised Inventory File (member of the Climate Team) in MEEN, who in turn provides the latest version of all relevant files (calculation files and NIR) to the Technical Assistance at the beginning of the next inventory cycle.

More specifically the information stored in the Centralised Inventory Files includes:

- A list of the reports, the input data files and the calculation/estimation files.
- The members of the Inventory Team.
- Final versions, in electronic format and hard copy, of the NIR.
- CRT tables in electronic format and a hard copy of the CRT tables for the last year covered by each submission.
- XML file and database of CRT reporter
- Calculation files, including the uncertainty estimation files.
- Expert review reports.
- Any comments from the public review of the inventory.
- Documentation derived from the implementation of the QA/QC procedures.

1.3.2 Quality assurance/quality control (QA/QC) procedures and extensive review of GHG inventory

Information pertaining to this section can be found in section 1.6.

1.4 Brief general description of methodologies and data sources used

1.4.1 GHG inventory

1.4.1.1 Emission factors

The estimation of GHG emissions / removals per source / sink category is based on the methods described in the 2006 IPCC Guidelines. The emission factors used derive from the above-mentioned methodological sources and special attention was paid in selecting the emission factors that better describe practices in Greece. Furthermore, emission factors were obtained from plant specific information contained in EU ETS reports. An overview of the methods applied for the calculation of emissions / removals is presented in ***Table 1.1***.

The key categories analysis (see Paragraph 1.5) constitutes the basic tool for methodological choice and for the prioritisation of the necessary improvements. In addition, the results of the various review processes (at national, European and international level) represent key input information for the identification of possible improvements. It should be mentioned however, that data availability as well as availability of resources (both human and financial) also have to be considered:

- Data availability could become a significant restrictive parameter when selecting an estimation methodology. The accuracy and the consistency of the emissions estimated depend on the availability of the data needed for the correct application of the selected methodology.
- Availability of resources needs also to be considered as the searching for and the collection of the necessary data in order to apply a detailed methodology for a source category should not affect the completeness and the on-time preparation of an inventory submission.

Table 1.1 Overview of methods applied for the calculation of GHG emissions / removals

	CO2		CH4		N2O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
1. Energy								
A. Fuel combustion								
1. Energy industries	T1,T2	D,PS	T1	D	T1	D		
2. Manufacturing industries and Construction	T1,T2	CS,D,PS	T1	D	T1	D		
3. Transport	T1,T2,T3	CS,D	M,T1,T2,T3	CR,D,M	M,T1,T2,T3	CR,D,M		
4. Other sectors	T1,T2	CS,D,NO	T1	D,NO	T1	D,NO		
5. Other	T1	D	T1	D	T1	D		
B. Fugitive emissions from fuels								
1. Solid fuels			T1	D				
2. Oil and Natural gas	T1	D	T1	D	T1	D		
2. Industrial processes								
A. Mineral products	CS,T1	CS,D,PS						
B. Chemical industry	T1,T1a	CS			CS	CS		
C. Metal production	CS,T1	CS,D,PS	CR	CR	NA	NA	T3	PS
D. Non-energy products from fuels and solvent use	D,T1	D						
E. Production of halocarbons and SF_6							T1, NA	D, NA
F. Consumption of halocarbons and SF_6							CS,T2	D,CS
G. Other product manufacture and use	T1	D			OTH	OTH	CS	CS
3. Agriculture								
A. Enteric fermentation			T1,T2	CS,D				
B. Manure management			T1,T2	CS,D	D	D		

	CO2		CH4		N2O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
C. Rice cultivation			T1	D				
D. Agricultural soils					T1	D		
F. Field burning of agricultural residues			T1	D	T1	D		
5. Land Use, Land Use Change and Forestry								
A. Forest land	OTH,T1,T2	CS,D,OTH	T1	D	T1	D		
B. Cropland	T1,T2	CS,D	NA	NA	T1	D		
C. Grassland	T1,T2	CS,D	T1	D	T1	D		
D. Wetlands	T1,T2	CS,D	NA	NA	T1	D		
E. Settlements	T1,T2	CS,D	NA	NA	T1	D		
F. Other Land	T1,T2	CS,D	NA	NA	T1	D		
G. HWP	T2	D	NA	NA	NA	NA		
6. Waste								
A. Solid waste disposal on land			T2	CS,D				
B. Wastewater handling			D	D	D	D		
C. Waste incineration	D	D, CS	D	CS	D	CS		
D. Waste water treatment and discharge			D	D	D	CS		

CR = CORINAIR, CS = Country Specific, PS = Plant Specific
NE = Not Estimated, NA= Not Applicable, NO= Not Observed, OTH= Other
T1, T1a, T1b, T2, T2a, T3b = IPCC T1, T1a, T1b, T2, T2a, T3b methodology respectively
D = Default IPCC methodology and emission factor
IE = Included Elsewhere
M = Copert IV model

1.4.1.2 Activity data

Data collection, processing and check constitute the activity with the longest duration in the annual inventory cycle. The duration of this activity is related to the amount of the necessary data and the number of the entities involved. The on-time and successful completion of this activity has a major effect on the timeliness preparation and submission of the inventory as well as on its accuracy, completeness and consistency.

Table 1.2 gives an overview of the main data sets used for the estimation of GHG emissions / removals. Data from international organizations and databases are supplementary to the data collected from the above data providers.

It should be noted that information and data collected (through questionnaires developed according to the guidelines described in the Commission Decision 2004/156/EC) in the framework of the formulation of the National Allocation Plan (NAP) for the period 2005 – 2007, according to the EU Directive 2003/87/EC (and its transposition to the national Law, JMD 2004) along with the data from the verified reports from installations under the EU ETS for years 2005-2023 constituted a significant source of information and an additional quality control check.

Table 1.2 Data sources and data sets per IPCC sector, source category

SECTOR		STATISTICAL DATA	DATA SOURCES
1.A1	Electricity generation	Fuel consumption	• Public Power Corporation • Ministry of Environment and Energy • ETS verified reports
1.A2	Manufacturing industry and construction	Fuel consumption	• Ministry of Environment and Energy • ETS verified reports
1.A3	Transport	Number of vehicles Aircraft landing and take off cycles	• Ministry of Infrastructure and Transport • Hellenic Statistical Authority • Association of Greek Auto Importers • Civil Aviation Organization
1.A4	Residential / Tertiary sector / Agriculture	Fuel consumption	• Ministry of Environment and Energy
1.B	Fugitive emissions from fuels	Amount of fuels Transmission/distribution pipelines length	• Ministry of Environment and Energy
2	IPPU	Industrial production and amount of solvents/other products use	• Hellenic Statistical Authority • Industrial units • ETS verified reports • Market surveys • National Association of Refrigerating and Cooling Technicians • Hellenic Aerosol Association • Public Power Corporation • National Organization of Medicines • Private companies
3	Agriculture	Cultivated areas Agricultural production Livestock population Fertilizer use	• Hellenic Statistical Authority • Ministry of Rural Development and Food • UN Food and Agricultural Organisation • Pan-Hellenic Association of Professional Fertilizers Producers & Dealers
4	Land Use, Land Use Change and Forestry	Area and wood stocks of managed forests Forest and grassland area affected by wildfires Afforestation and Deforestation areas Cultivated areas and areas of other land uses	• Ministry of Environment and Energy • Hellenic Statistical Authority • Greek Payment Authority of Common Agricultural Policy Aid Schemes (OPEKEPE) • UN Food and Agricultural Organisation
5	Waste	Quantities - composition of solid waste generated Recycling Population Industrial production	• Ministry of Environment and Energy • Association of Communities and Municipalities in the Attica Region (ACMAR) • Hellenic Statistical Authority • UN Food and Agricultural Organisation

1.4.1.3 Global warming potential

Emissions from anthropogenic activities affect the concentration and distribution of greenhouse gases in the atmosphere. These changes can potentially produce a radiative forcing of the Earth's surface and lower atmosphere, by changing either the reflection or absorption of solar radiation or the emissions and absorption of long-wave radiation.

A simple measure of the relative radiative effects of the emissions of various greenhouse gases is the Global Warming Potential (GWP) index. This index is defined as the cumulative radiative forcing between the present and some chosen time-horizon caused by a unit mass of gas emitted now, expressed relative to that for some reference gas. In this submission, the values from IPCC AR5 were applied, in line with Commission Delegated Regulation (EU) 2020/1044. The values for GWP for some of the most potent greenhouse gases are given in ***Table 1.3***.

Corresponding values of GWP for other gases (NOx, CO, NMVOC) are not given by the IPCC (nor by other sources for this purpose), since at present it is impossible to calculate the indirect results of these gases, as the scientific knowledge on their chemical reactions taking place in the atmosphere is not sufficient.

Table 1.3 Global Warming Potential (in t of CO_2 eq) for the 100-year horizon

Gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous oxide (N_2O)	265
Hydrofluorocarbons (HFC)	
HFC-23	Please refer to Commission Delegated Regulation (EU) 2020/1044
HFC-32	
HFC-125	
HFC-134a	
HFC-143a	
HFC-152a	
HFC-227ea	
HFC-236fa	
HFC-4310mee	
Perfluorocarbons (PFC)	
CF_4	
C_2F_6	
C_4F_{10}	
C_6F_{14}	
Sulphur hexafluoride (SF_6)	

1.5 Brief description of key categories

1.5.1 GHG inventory

The 2006 IPCC Guidelines define procedures (in the form of decision trees) for the choice of estimation methods within the context of the IPCC Guidelines. Decision trees formalize the choice of the estimation method most suited to national circumstances considering at the same time the need for accuracy and the available resources (both financial and human). Generally, inventory uncertainty is lower when emissions are estimated using the most rigorous methods, but due to finite resources, this may not be feasible for every source category. Therefore, it is good practice to identify those source categories (key source categories) that have the greatest contribution to overall inventory uncertainty in order to make the most efficient use of available resources.

In that context, a *key source category* is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions (level assessment) or/and to the trend of emissions (trend assessment). As far as possible, key source categories should receive special consideration in terms of two important inventory aspects:

- The use of source category-specific good practice methods is preferable, unless resources are unavailable.
- The key source categories should receive additional attention with respect to quality assurance (QA) and quality control (QC).

As a result of the adoption of the LULUCF Good Practice Guidance (Decision 13/CP.9) the concept of key sources has been expanded in order to cover LULUCF emissions by sources and removals by sinks. Therefore, the term key category is used in order to include both sources and sinks.

The determination of the key categories for the Greek inventory system is based on the application of the Tier 1 methodology (see Annex I for an analytic presentation of calculations) described in the 2006 IPCC Guidelines.

Tier 1 methodology for the identification of key categories assesses the impacts of various source categories on the level and the trend of the national emissions inventory. Key categories are those which, when summed together in descending order of magnitude, add up to over 95% of total emissions (level assessment) or the trend of the inventory in absolute terms.

It should be mentioned that:

- Source category uncertainty estimates are not taken into consideration.
- Base year estimates were calculated considering 1990 as base year.

The key categories for the Greek inventory system (without *LULUCF*) and for the year 2023 are presented in ***Table 1.4.***

Thirteen key source categories are found in the energy sector, six in the IPPU sector, five in agriculture and two in waste sector in 2023 (without *LULUCF*).

Table 1.4 Key categories for the Greek inventory system without LULUCF for 2023

Quantitative method used	Tier 1		
IPCC source categories	GHG	Criteria for identification	
		Level	Trend
ENERGY SECTOR			
Fuel combustion - Energy Industries - Liquid Fuels	CO2	X	X
Fuel combustion - Energy Industries - Solid Fuels	CO2	X	X
Fuel combustion - Energy Industries - Gaseous Fuels	CO2	X	X
Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X	X
Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	X	X
Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2		X
Domestic Aviation	CO2	X	
Road Transportation	CO2	X	X
Domestic Navigation - Liquid Fuels	CO2	X	X
Other Sectors - Liquid Fuels	CO2	X	X
Other Sectors - Gaseous Fuels	CO2	X	X
Other (Not specified elsewhere) - Liquid Fuels	CO2	X	X
Fugitive emissions from Solid Fuels	CH4		X
INDUSTRIAL PROCESSES SECTOR			
Cement Production	CO2	X	X
Ammonia Production	CO2		X
Other	CO2	X	X
Nitric Acid Production	N2O		X
Aluminium Production	CO2	X	
Refrigeration and Air conditioning	Aggregate F-gases	X	X
AGRICULTURE			
Enteric Fermentation	CH4	X	X
Manure Management	CH4	X	
Manure Management	N2O	X	
Direct N2O Emissions From Managed Soils	N2O	X	X
Indirect N2O Emissions From Managed Soils	N2O	X	
WASTE			
Solid Waste Disposal	CH4	X	X
Wastewater Treatment and Discharge	CH4	X	X

The methodology applied for the determination of the key categories with *LULUCF* is similar to the one presented above. The key categories identified for the year 2023 are presented in ***Table 1.5*** (see Annex I for an analytic presentation). The comparison of the results of the analysis with and without *LULUCF* reveals small differences in the source categories identified (apart from the categories from the LULUCF sector). In the analysis including LULUCF, fourteen categories from the Energy Sector, six from the IPPU sector, five from agriculture, two from waste sector and five from LULUCF have been identified as key.

Table 1.5 Key categories for the Greek inventory system with LULUCF for 2022

Quantitative method used	Tier 1			
IPCC source categories	GHG	Criteria for identification		Key category including LULUCF
		Level	Trend	
ENERGY SECTOR				
Fuel combustion - Energy Industries - Liquid Fuels	CO2	X	X	X
Fuel combustion - Energy Industries - Solid Fuels	CO2	X	X	X
Fuel combustion - Energy Industries - Gaseous Fuels	CO2	X	X	X
Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X	X	X
Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	X	X	X
Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2		X	X
Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2		X	X
Domestic Aviation	CO2	X		X
Road Transportation	CO2	X	X	X
Domestic Navigation - Liquid Fuels	CO2	X	X	X
Other Sectors - Liquid Fuels	CO2	X	X	X
Other Sectors - Gaseous Fuels	CO2	X	X	X
Other (Not specified elsewhere) - Liquid Fuels	CO2	X	X	X
Fugitive emissions from Solid Fuels	CH4		X	X
INDUSTRIAL PROCESSES SECTOR				
Cement Production	CO2	X	X	X
Ammonia Production	CO2		X	X
Other	CO2	X	X	X
Nitric Acid Production	N2O		X	X
Aluminium Production	CO2	X		X
Refrigeration and Air conditioning	Aggregate F-gases	X	X	X
AGRICULTURE				
Enteric Fermentation	CH4	X	X	X
Manure Management	CH4	X		X
Manure Management	N2O	X		X
Direct N2O Emissions From Managed Soils	N2O	X	X	X
Indirect N2O Emissions From Managed Soils	N2O	X		X
WASTE				
Solid Waste Disposal	CH4	X	X	X
Wastewater Treatment and Discharge	CH4	X	X	X
LULUCF				
Biomass Burning	CH4	X	X	X
Forest Land Remaining Forest Land	CO2	X		X
Cropland Remaining Cropland	CO2	X		X
Land Converted to Grassland	CO2	X	X	X
Harvested Wood Products	CO2		X	X

1.6 Information on the QA/QC plan including verification and treatment of confidentiality issues where relevant

1.6.1 QA/QC procedures and verification activities

The development and the implementation of an inventory Quality Assurance / Quality Control (QA/QC) plan represents a key tool for meeting the objectives of National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7.

With the Protocol's application, the pressure upon national GHG emissions inventories increases and therefore quality management is essential in order to comply with the requirements of (a) producing transparent, consistent, comparable, complete and accurate emissions estimates, (b) establishing a reliable central archiving system concerning all necessary information for GHG emissions inventories development and (c) compiling national reports according to the provisions of the adopted decisions.

In this framework, a QA/QC system is being implemented since April 2004. For the implementation of the QA/QC system NTUA is responsible in close co-operation with the MEEN. The system is based on the ISO 9001:2000 standard and its quality objectives, as stated in the quality management handbook, are the following:

1. Compliance with the 2006 IPCC guidelines and the UNFCCC reporting guidelines while estimating and reporting emissions/removals.
2. Continuous improvement of GHG emissions/removals estimates.
3. Timely submission of necessary information in compliance with relevant requirements defined in international conventions, protocols and agreements.

The accomplishment of the above-mentioned objectives can only be ensured by the implementation, from all the members of the Inventory Team (see ***Figure 1.4*** for the flow chart of activities concerning emissions inventory), of the QA/QC procedures included in the plan for:

- data collection and processing,
- applying methods consistent with 2006 IPCC Guidelines for calculating / recalculating emissions or removals, and 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol
- making quantitative estimates of inventory uncertainty,
- archiving information and record keeping and
- compiling national inventory reports.

The QA/QC system developed covers the following processes (see ***Table 1.7*** for the list of procedures within each process and ***Figure 1.5*** for the relationship between the processes and the activities of the inventory team):

- **QA/QC system management**, comprising all activities that are necessary for the management and control of the inventory agency in order to ensure the accomplishment of the above-mentioned quality objectives.
- **Quality control,** that is directly related to the estimation of emissions. The process includes activities related to (a) data inquiry, collection and documentation, (b) methodological choice in accordance with the 2006 IPCC Guidelines, (c) quality control checks for data from secondary sources and (d) record keeping.
- **Archiving inventory information**, comprising activities related to centralised archiving of inventory information and the compilation of the national inventory report.
- **Quality assurance**, comprising activities related to the different levels of review processes including the review of input data from experts, if necessary, and comments from the public
- **Estimation of uncertainties**, defining procedures for estimating and documenting uncertainty estimates per source / sink category and for the whole inventory.
- **Inventory improvement**, that is related to the preparation and the justification of any recalculations made.

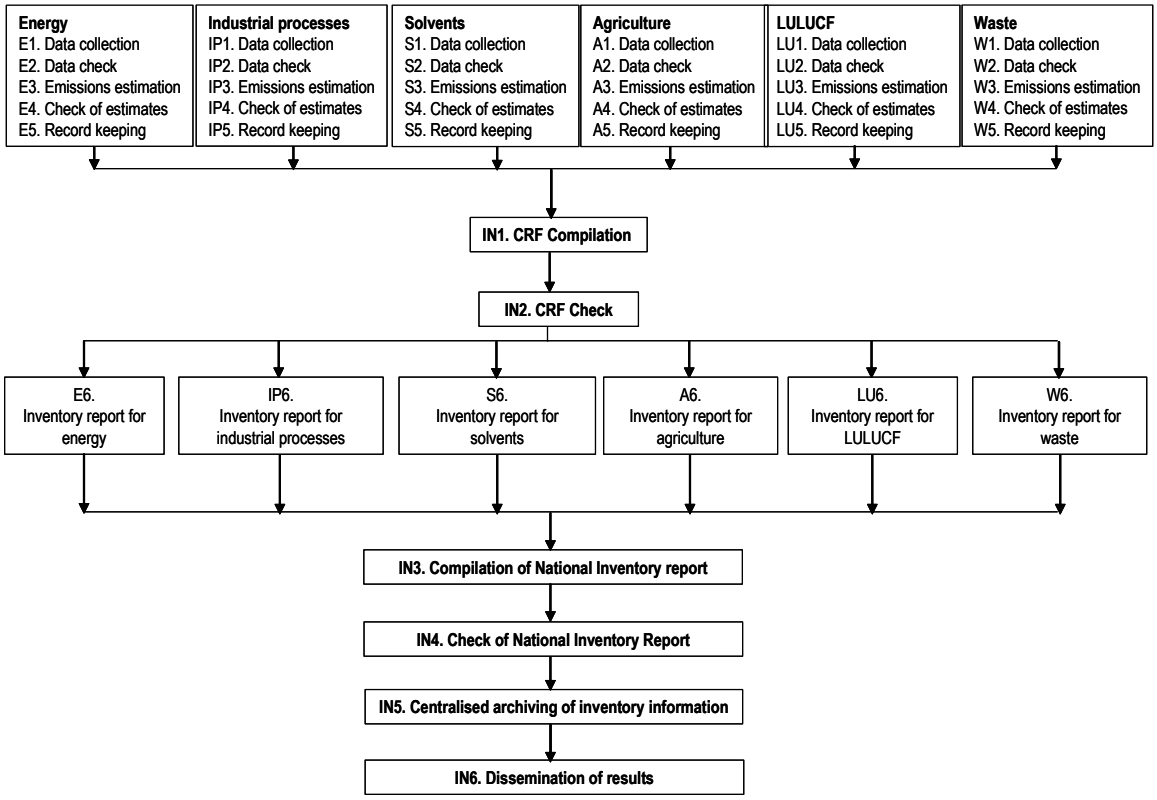


Figure 1.4 Flow chart activities concerning the GHG emissions inventory

Table 1.7 Quality assurance / quality control procedures for the Greek GHG emissions inventory

Process	Procedure code	Procedures
Quality management	QM 01	System review
	QM 02	System improvement
	QM 03	Training
	QM 04	Record keeping
	QM 05	Internal reviews
	QM 06	Non compliance – Corrective and preventive actions
	QM 07	Supplies
	QM 08	Quality management system
	QM 09	Documents control
	QM 10	Internal communication
Quality control	QC 01	Data collection
	QC 02	Estimation of emissions / removals
	QC 03	Data quality control check
	QC 04	Input data record keeping
Archiving of inventory information	AI 01	Centralised archiving of inventory information
	AI 02	Compilation of reports
Quality assurance	QA 01	Expert review of input data and parameters
	QA 02	Expert review of GHG emissions / removals inventory
	QA 03	Review from public
Estimation of uncertainties	EU 01	Uncertainty analysis
Inventory improvement	II 01	Recalculations management

All the procedures described in the QA/QC manual are followed by both MEEN and NTUA. As described in the chapters of the NIR entitled "Source-specific QA/QC and verification", source-specific Tier 2 QC procedures are applied in the majority of source categories for quality control and verification purposes.

Furthermore, annual internal audits take place by MEEN/NTUA between January and March of each year and audits by independent local experts are planned and implemented.

Each year the EU performs QA/QC checks (called initial checks) to its member states as a part of EU QA/QC system. These tests are performed annually between 15/1 to 28/2. These checks have been designed to verify the transparency, accuracy, consistency, comparability and completeness of the information submitted and include: (a) an assessment whether all emission source categories and gases required under Regulation (EU) No 525/2013 are reported; (b) an assessment whether emissions data time series are consistent; (c) an assessment whether implied emission factors across Member States are comparable taking the IPCC default emission factors for different national circumstances into account; (d) an assessment of the use of 'Not Estimated' notation keys where IPCC tier 1 methodologies exist and where the use of the notation key is not justified in accordance with paragraph 37 of the UNFCCC reporting guidelines on annual greenhouse gas inventories as included in Annex I to Decision 24/CP.19; (e) an analysis of recalculations

performed for the inventory submission, in particular if the recalculations are based on methodological changes; (f) a comparison of the verified emissions reported under the Union's Emissions Trading System with the greenhouse gas emissions reported pursuant to Article 7 of Regulation (EU) No 525/2013 with a view of identifying areas where the emission data and trends as submitted by the Member State under review deviate considerably from those of other Member States; (g) a comparison of the results of Eurostat's reference approach with the Member States' reference approach; (h) a comparison of the results of Eurostat's sectoral approach with the Member States' sectoral approach; (i) an assessment whether recommendations from earlier Union or UNFCCC reviews, not implemented by the Member State could lead to a technical correction; (j) an assessment whether there are potential overestimations or underestimations relating to a key category in a Member State's inventory.

Moreover, EU carries out comprehensive reviews (similar to centralized UNFCC reviews) of the national inventory data submitted by Member States. Three comprehensive reviews of the Greek inventory (all sectors except LULUCF) have been performed by EU, i.e. in 2012, 2016 and 2020. In 2013, a Bilateral QA exercise between the Spanish and the Greek Inventory teams was performed. The Spanish inventory team reviewed the Agriculture, Waste and IP (F-gases) sectors of the Greek inventory. On the other hand, the Greek inventory team reviewed the industrial combustion, industrial processes and waste sectors of the Spanish inventory.

Finally, in 2021 Greece participated in a voluntary Trial Review of the 2021 greenhouse gas inventory for the LULUCF sector. This review resulted in informal recommendations to improve the accuracy and transparency of the inventory. The first step of the LULUCF trial review was performed by the Joint Research Centre (JRC), partly on basis of newly developed checks by the European Environment Agency (EEA) and the European Topic Centre for Climate Change Mitigation and Energy (ETC/CME). In the second step of the LULUCF trial review a Technical Expert Review Team (TERT) performed checks pursuant to Article 38 of the Governance Regulation (Regulation (EU) 2018/1999), and Article 30 and Annex XXII of the Implementing Regulation (Regulation (EU) 2020/1208) including requirements as defined by the 2006 IPCC Guidelines and findings from the United National Framework Convention on Climate Change (UNFCCC) reviews. The objective at this stage, both in this trial setting as well as during the real comprehensive review in 2027, was to ensure that inventory data are prepared in a manner consistent with the UNFCCC guidance documentation and European Union rules, particularly those requirements set out in the LULUCF Regulation.

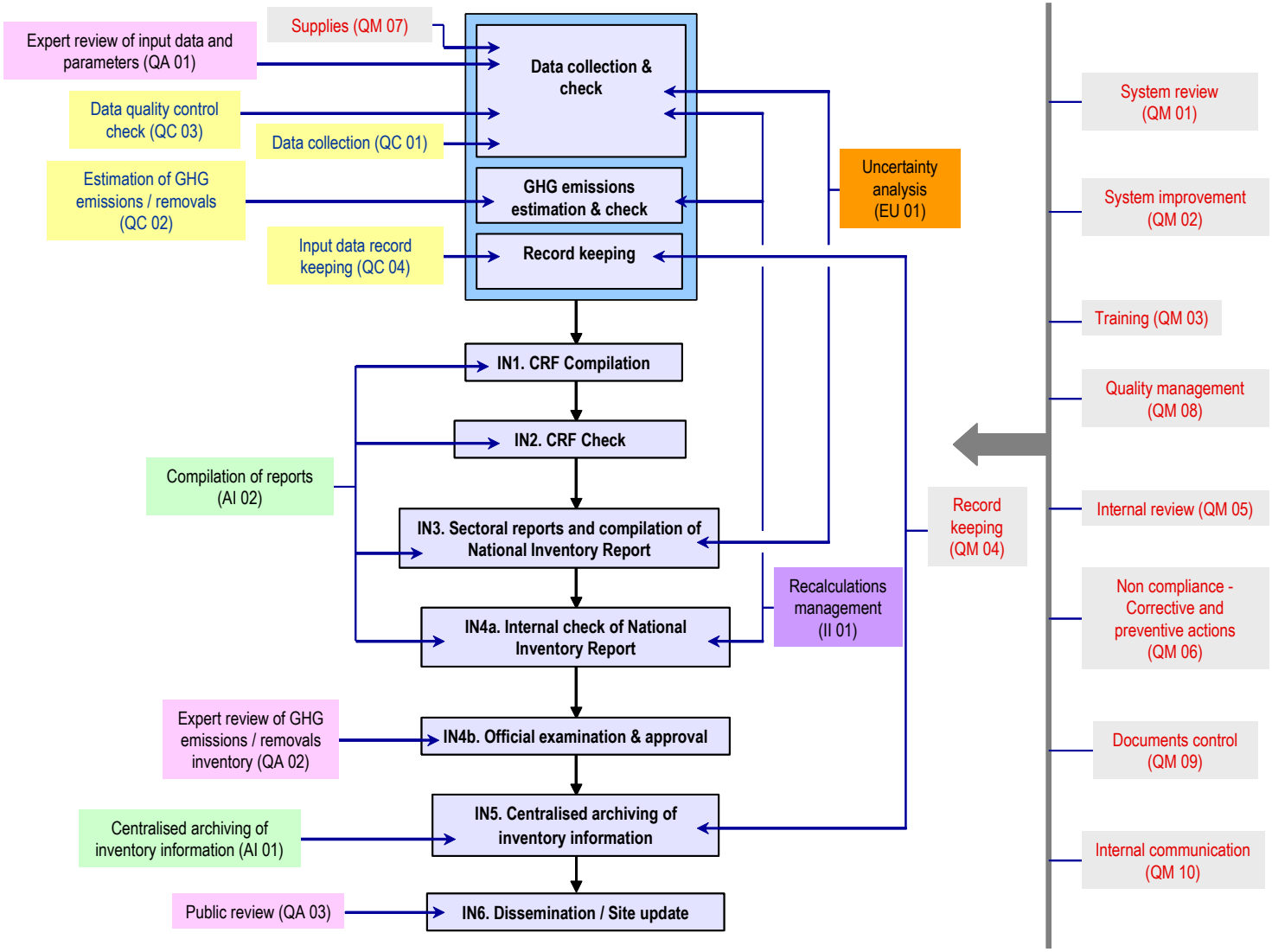


Figure 1.5 QA/QC processes and procedures and inventory related activities

1.6.2 Treatment of confidentiality issues

Confidentiality issues concern mainly the Industrial Processes sector in cases where the activity data relate directly to the production activity of one plant. This is the case in some of categories of the industrial processes sector, although most of them fall under the ETS reporting system.

The provision of data that are concerned as confidential is quite difficult, since these data are not published in the national statistics.

In the past, there were also procedures of confidential data exchange between the inventory team and the Hellenic Statistics Authority (El.Stat). More specifically, the cooperation established under this system contributed to the confidentiality waiver that was decided by the relevant committee of the Service in 2008. The received data have been entered in Greece's QA/QC input file and are constantly used as primary data or in QA/QC checks (see also Chapter 4: Industrial Processes). Moreover, whenever a confidentiality issue arise, the inventory system is working in close cooperation with the Prodcom Section of the ElStat., throughout all the stages of the inventory preparation and during the reviews if necessary. It should be also mentioned that in any case, the El. Stat. provides the inventory team with all the information regarding the plant's id, information that has also been considered as confidential in the past.

In the recent years, the most efficient way for collecting such information is by communicating directly to the respective plants, building a very good cooperation between the plants and the inventory team and ensuring that the published data are the most updated.

Finally, in a number of cases activity data are reported as confidential in the inventory files. This happens in cases when the inventory team has not received an official approval by the corresponding industry in order to publish direct activity data. It should be noted, however, that in any case the activity data are kept in the Input File of the inventory and are made available at any request during the review processes.

In cases, such as the aluminium production in the past, the inventory team, based on the respective recommendation by the 2010 ERT, has reported the aluminium production as provided by international and national sources (Greek Mining Enterprises Association, US Geological Survey). It should be noted that this production differs slightly from the one reported by the plant itself in accuracy and also due to the fact that in some cases provisional estimations may have been used by the other sources.

1.7 General uncertainty evaluation

1.7.1 GHG inventory

In order to evaluate the accuracy of an emissions inventory, an uncertainty analysis has to be carried out for both annual estimates of emissions and emissions trends over time.

The estimated uncertainty of emissions from individual sources (e.g. power plants, motor vehicles) is either a function of instrument characteristics, calibration and sampling frequency of direct measurements, or (more often) a combination of the uncertainties in the emission factors for typical sources and the corresponding activity data.

- Emission factors reported in the literature usually derive from measurements at specific installations, the characteristics of which are judged to be typical for a set of similar installations. The validity of this assumption given the national circumstances represents the crucial factor determining uncertainty.
- Activity data are more closely linked to economic activity than are emission factors. Therefore, there are often well established incentives requirements for accurate accounting. As a result activity data tend to have lower uncertainties and lower correlation between years. Data availability at the level of analysis required for the estimation of GHG emissions / removals as well as the definitions used by the statistical agencies represent some of the parameters affecting the uncertainty of activity data.

Detailed explanation regarding the choice of the uncertainty values on the activity data and emission factors estimations is presented in Annex IV.

The uncertainty analysis for the Greek GHG inventory is based on Tier 1 methodology described in the 2006 IPCC Guidelines, with 1990 as base year for CO_2, CH_4, N_2O and F-gases emissions.

- For the estimation of uncertainties per gas, a combination of the information provided by the IPCC and critical evaluation of information from indigenous sources was applied.
- The uncertainty analysis was carried out both without and with the *LULUCF* sector.

Table 1.8 presents the uncertainty estimates by source category and by gas (without *LULUCF*), while the detailed calculations are presented in Annex IV.

The uncertainty estimates for GHG emissions per gas in 2023, were estimated at:

- 2.8% for CO_2 emissions
- 23.5% for CH_4 emissions
- 108.7% for N_2O emissions and
- 269.1% for the F-gases emissions.

Table 1.8 Uncertainty estimates per source category and gas (without LULUCF)

Source categories	Gas	Uncertainty (%)
1.A Fuel Combustion Activities-Liquid	CO_2	4.2%
1.A Fuel Combustion Activities-Solid		4.2%
1.A Fuel Combustion Activities-Gas		3.6%
1.A Fuel Combustion Activities-Other fossil fuels		4.2%
1.B.2 Oil and Natural Gas		300.0%
2.A.1 Cement Production		2.8%
2.A.2 Lime Production		7.8%
2.A.3 Glass production		5.8%
2.A.4 Other process uses of carbonates		11.2%
2.B.1 Ammonia Production		6.7%
2.B.8 Petrochemical and Carbon Black Production		7.1%
2.B.10 Other-Hydrogen production		4.2%
2.C.1 Iron and Steel Production		7.1%
2.C.2 Ferroalloys		9.9%
2.C.3 Aluminium Production		2.8%
2.C.5 Lead production		20.1%
2.C.6 Zinc production		20.1%
2.D.1 Lubricant Use		7.1%
2.D.2 Paraffin Wax Use		7.1%
2.D.3 Emissions from the use of urea as a catalyst		4.2
2.G.4 Other product manufacture and use		7.1%
3.H Urea application		53.9%
5. Incineration and open burning of waste		111.8%
Total CO_2		**2.8%**
1.A.1 Energy Industry-Liquid	CH_4	100.0%
1.A.1 Energy Industry-Solid		100.0%
1.A.1 Energy Industry-Gas		100.0%
1.A.1 Energy Industry-Biomass		100.0%
1.A.2 Industries and Construction-Liquid		100.0%
1.A.2 Industries and Construction-Solid		100.0%
1.A.2 Industries and Construction-Gas		100.0%
1.A.2 Industries and Construction-Other fossil fuels		100.0%
1.A.2 Industries and Construction-Biomass		100.0%
a. Domestic aviation		100.1%
b. Road Transportation		40.2%
c. Railways		100.1%
d. Domestic Navigation		100.1%
e. Other Transportation		100.1%
1.A.4 Other Sectors-Liquid		100.0%
1.A.4 Other Sectors-Solid		100.0%
1.A.4 Other Sectors-Gas		100.0%
1.A.4 Other Sectors-Biomass		100.0%

Table 1.8(cont.) Uncertainty estimates per source category and gas (without LULUCF)

Source categories	Gas	Uncertainty (%)
1B Coal Mining	CH_4	300.0%
1.B.2 Oil and Natural Gas		300.0%
2.B.8 Petrochemical and Carbon Black Production		7.1%
2.C.1 Iron and Steel Production		6.4%
3.A Enteric Fermentation		50.2%
3.B Manure Management		30.4%
3.C Rice Cultivation		40.0%
3.F Field burning of agricultural residues		28.3%
5.A.1 Managed waste disposal sites		84.9%
5.A.1 Unmanaged waste disposal sites		84.9%
5.B.1 Biological treatment of solid waste-Composting		104.4%
5. Incineration and open burning of waste		111.8%
5.D.1 Domestic Wastewater Treatment and Discharge		42.4%
5.D.2 Industrial Wastewater Treatment and Discharge		42.4%
Total CH_4		**23.5%**
1.A.1 Energy Industry-Liquid	N_2O	300.0%
1.A.1 Energy Industry-Solid		300.0%
1.A.1 Energy Industry-Gas		300.0%
1.A.1 Energy Industry-Biomass		300.0%
1.A.2 Industries and Construction-Liquid		300.0%
1.A.2 Industries and Construction-Solid		300.0%
1.A.2 Industries and Construction-Gas		300.0%
1.A.2 Industries and Construction-Other fossil fuels		300.0%
1.A.2 Industries and Construction-Biomass		300.0%
a. Domestic aviation		300.0%
b. Road Transportation		50.2%
c. Railways		300.0%
d. Domestic Navigation		300.0%
e. Other Transportation		300.0%
1.A.4 Other Sectors-Liquid		300.0%
1.A.4 Other Sectors-Solid		300.0%
1.A.4 Other Sectors-Gas		300.0%
1.A.4 Other Sectors-Biomass		300.0%
1.B.2 Oil and Natural Gas		300.0%
2.B.2 Nitric acid production		3.6%
2.G.3 N2O from Product Uses		7.1%
3.B Manure Management		100.1%
3.D Direct N2O Emissions from Agricultural Soils		201.0%
3.D Indirect N2O Emissions from Managed Soils		53.9%
3.F Field burning of agricultural residues		28.3%
5.B.1 Biological treatment of solid waste-Composting		104.4%
5. Incineration and open burning of waste		111.8%
5.D.1 Domestic Wastewater Treatment and Discharge		42.4%

5.D.2 Industrial Wastewater Treatment and Discharge		104.4%
Total N_2O		**108.7%**
2.B.9 Flurochemical production	**F-gases**	70.7%
2.F.1 Refrigeration and Air-Conditioning Equipment		180.3%
2.F.2 Foam Blowing		64.0%
2.F.3 Fire Extinguishers		60.8%
2.F.4 Aerosols		15.8%
2.C.3 Aluminium Production		6.7%
2.F.1 Refrigeration and Air-Conditioning Equipment		180.3%
2.C.4. Magnesium production		53.9%
2.G.1 Electrical Equipment		53.9%
Total F-gases		**269.1**
Total uncertainty (%)		**12.6**

In general, the uncertainties associated with CO_2 are very low, while the least accurate estimations are those for N_2O and F-gases. This difference is mainly due to the uncertainty in emissions factors. For example, in the sector of marine transport the emission factor for CO_2 depends only on the type of fuel, while CH_4 and N_2O factors depend heavily on the technology of the engine used. As a result, the uncertainty in emissions factors for marine transport is 5% for CO_2 and an order of magnitude for CH_4 and N_2O.

Total uncertainty is 12.6% (without *LULUCF*), while the uncertainty that carried over into the GHG emissions trend is 8.9%. To be mentioned that the uncertainty analysis is based on the 100% of emissions.

The results of the uncertainty analysis for the *LULUCF* sector are presented in ***Table 1.9***. The uncertainty estimates for GHG emissions per gas, with LULUCF, in 2023, were estimated at (the detailed calculations are presented in Annex IV):

- 4.2% for CO_2 emissions,
- 22.7% for CH_4 emissions,
- 107.6% for N_2O emissions and
- 269.1% for the F-gases emissions.

Total uncertainty is 13.5%, while the uncertainty that carried over into the GHG emissions trend is 9.1%.

Table 1.9 Uncertainty analysis for the LULUCF sector

Source / Sink categories	Gas	Uncertainty (%)
Forest Land remaining Forest Land	**CO2**	18
Land converted to Forest Land	**CO2**	76
Cropland remaining Cropland	**CO2**	109
Land converted to Cropland	**CO2**	27
Grassland remaining Grassland	**CO2**	43

Land converted to Grassland	**CO2**	34
Land converted to Wetlands	**CO2**	43
Land converted to Settlements	**CO2**	27
Land converted to Other Land	**CO2**	32
Harvested Wood Products	**CO2**	50
Forest Land remaining Forest Land	**CH4**	57
Land converted to Forest Land	**CH4**	62
Grassland remaining Grassland	**CH4**	57
Forest Land remaining Forest Land	**N2O**	57
Land converted to Forest Land	**N2O**	62
Land converted to Cropland	**N2O**	41
Grassland remaining Grassland	**N2O**	57
Land converted to Grassland	**N2O**	61
Land converted to Wetlands	**N2O**	51
Land converted to Settlements	**N2O**	51
Land converted to Other Land	**N2O**	71

1.8 General assessment of the completeness

1.8.1 GHG inventory

In the present inventory report, which supersedes all previous ones, estimates of GHG emissions in Greece for the years 1990-2020 are presented. Emissions estimates included in the CRT tables submitted and discussed in the present report, cover the whole territory of Greece. All major sources are reported including emissions estimates for indirect greenhouse gases and SO_2.

Completeness gaps in the present inventory submission that will be discussed in more details in the relevant chapters include:

- CO_2 emissions from *organic chemicals production* and *asphalt roofing-road paving with asphalt* are not estimated due to lack of emission factors in the IPCC guidelines.

Further, the following sources were reported as "NE" because they were considered insignificant in line with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines:

1. 1.B.2.a. Oil: CO2, CH4 and N2O emissions from the exploration of oil and CO2 emissions from oil transport were reported as "NE" (not estimated). These emissions are considered insignificant, as defined in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, because of the low level of crude oil production (Tables 3.29a). For example, by applying the tier 1 2006 IPCC methodology, the CO2, CH4 and N2O emissions from the exploration of oil will be less than 3 ktCO2eq (please refer to section 3.3.3).
2. 1.B.2.b. Natural Gas: CO2 and CH4 emissions from the exploration of natural gas were reported as "NE" (not estimated). These emissions are considered insignificant, as defined in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, because of the low level of NG production (Tables 3.29b). For example, by applying the tier 1 2006 IPCC methodology, the CO2 and CH4 emissions from the exploration of oil will be less than 3 ktCO2eq (please refer to section 3.3.3).
3. 3.D.a.5 Mineralization/immobilization associated with loss/gain of soil organic matter – N2O: According to proxy estimations of N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management equal to 5,427,544 kg N/year, which would result in emissions of 0.085 kt N2O/year, or 25.41 kt CO2 eq/year. This amount is below the significance threshold indicated in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines.

As it can be concluded from the above information, the total national aggregate of the estimated emissions for all gases and categories considered insignificant remains below 0.1 per cent of the national total GHG emissions

2. Trends in greenhouse gas emissions

2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions

The GHG emissions trends (CO_2, CH_4, N_2O, HFC, PFC and SF_6) for the period 1990 – 2023 are presented in ***Table 2.1*** (in kt CO_2 eq). The GWP values used for the conversion of emissions estimates into the common unit of carbon dioxide equivalent are those presented in ***Table 1.3***.

It is noted that according to the IPCC Guidelines, emissions estimates for international marine and aviation bunkers were not included in the national totals, however they are reported separately as memo items.

UNFCCC base year GHG emissions for Greece (year 1990) were estimated at 101.72 Mt CO2 eq (without LULUCF) and 103.99 Mt CO2 eq with LULUCF.

In 2023, GHG emissions (without LULUCF) amounted to 71.93 Mt CO2 eq showing a decrease of 30.82% compared to 1990 levels. If emissions / removals from LULUCF were to be included, then the decrease would be 33.31%

Carbon dioxide emissions accounted for 72.27% of total GHG emissions in 2023 (without LULUCF) and decreased by 37.69% from 1990 (41.66% with LULUCF). Methane emissions accounted for 16.20% of total GHG emissions in 2023 (without LULUCF) and decreased by 7.0% from 1990, while nitrous oxide emissions accounted for 5.16% of the total GHG emissions in 2023 and decreased by 45.85% from 1990. Finally, f-gases emissions (from production and consumption) that accounted for 6.24% of total GHG emissions in 2023 were increased by 29.21% from 1995.

Table 2.1a Total GHG emissions in Greece (in kt CO2 eq) for the period 1990-2004

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
A. GHG emissions per gas (excluding LULUCF)															
CO_2	83,438.04	83,407.50	84,975.66	84,284.96	86,430.25	86,963.21	89,114.95	93,801.54	98,621.80	97,934.81	102,973.18	105,361.88	105,000.51	109,066.72	109,485.27
CH_4	12,526.76	12,513.86	12,588.60	12,639.37	12,714.45	12,913.16	13,093.12	13,041.52	13,279.69	13,237.92	13,244.44	12,469.73	12,565.28	12,680.96	12,707.31
N_2O	6,855.77	6,736.87	6,588.65	6,095.98	5,973.97	6,157.05	6,308.90	6,166.36	6,091.67	6,047.55	5,867.17	5,740.05	5,694.40	5,624.06	5,628.87
HFC	991.01	1,173.04	962.74	1,702.86	2,272.32	3,487.68	4,046.99	4,344.36	4,856.97	5,667.03	4,460.65	4,079.50	4,375.21	4,112.54	4,309.68
PFC	171.09	171.93	168.83	101.56	63.23	56.52	48.32	113.00	139.86	94.78	110.09	75.81	79.64	80.61	79.37
SF_6	3.02	3.11	3.21	3.30	3.39	3.53	3.62	3.67	3.71	3.81	3.92	4.00	4.18	4.18	4.39
Total	**103,985.69**	**104,006.32**	**105,287.68**	**104,828.03**	**107,457.62**	**109,581.14**	**112,615.89**	**117,470.44**	**122,993.71**	**122,985.88**	**126,659.44**	**127,730.96**	**127,719.22**	**131,569.08**	**132,214.90**
B. GHG emissions/removals from LULUCF															
CO_2	-2,355.55	-2,451.33	-2,716.68	-3,190.93	-2,922.76	-3,135.14	-2,436.97	-2,271.58	-2,414.96	-2,765.71	-2,780.33	-2,689.55	-3,007.06	-2,761.21	-2,750.41
CH_4 in kt	2.51	1.24	3.67	3.28	3.06	1.74	1.05	2.31	6.31	0.48	8.32	1.12	0.15	0.21	0.54
N_2O in kt	0.02	0.02	0.04	0.04	0.04	0.03	0.03	0.04	0.07	0.03	0.09	0.04	0.04	0.04	0.05
Total	**-2,279.61**	**-2,412.13**	**-2,604.37**	**-3,089.61**	**-2,827.54**	**-3,078.82**	**-2,400.45**	**-2,196.63**	**-2,220.27**	**-2,744.08**	**-2,523.73**	**-2,646.56**	**-2,992.17**	**-2,743.79**	**-2,722.39**
C. GHG Emissions from International Transport															
CO_2	14,136.62	14,932.09	15,294.12	15,460.88	15,753.14	16,084.99	16,535.05	17,236.86	18,998.77	19,311.12	18,364.24	19,227.92	19,553.34	20,628.46	21,024.82
CH_4 in kt	123.66	124.88	123.58	124.92	124.62	125.99	126.47	128.78	133.36	136.92	137.72	141.31	139.52	138.49	139.75
N_2O in kt	242.36	255.57	272.47	298.66	318.79	329.67	324.14	350.38	418.17	429.38	308.58	343.43	341.55	337.60	349.19
Total	**14,502.64**	**15,312.54**	**15,690.17**	**15,884.46**	**16,196.55**	**16,540.64**	**16,985.66**	**17,716.01**	**19,550.30**	**19,877.42**	**18,810.54**	**19,712.66**	**20,034.41**	**21,104.54**	**21,513.76**

Table 2.1b Total GHG emissions in Greece (in kt CO2 eq) for the period 2005-2023

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
A. GHG emissions per gas (excluding LULUCF)																			
CO_2	113,888.96	112,419.55	114,545.69	111,080.35	104,319.84	97,354.14	94,505.22	91,392.59	81,713.25	78,635.69	74,926.67	71,359.61	74,841.75	71,778.09	65,736.32	55,576.93	57,527.91	57,609.05	51,988.22
CH_4	12,798.54	12,882.80	12,777.13	12,643.73	12,251.93	12,505.24	12,344.49	12,170.19	11,904.56	11,697.28	11,486.37	11,113.80	11,462.64	11,621.66	11,389.49	11,380.26	11,750.50	11,769.10	11,650.25
N_2O	5,467.73	5,311.31	5,399.06	5,184.78	4,860.91	5,035.28	4,821.51	4,441.49	4,171.65	3,972.23	3,904.74	3,952.14	4,016.62	3,924.41	3,914.53	3,961.99	3,942.88	3,741.15	3,712.24
HFC	4,503.29	2,568.97	3,058.38	3,494.70	3,805.73	4,215.53	4,480.25	4,864.48	5,403.54	5,505.32	5,641.71	5,844.57	5,806.45	5,559.42	5,137.08	4,816.27	4,675.61	4,558.17	4,491.83
PFC	82.70	78.87	93.29	107.64	82.83	117.35	100.08	133.83	156.13	121.65	108.05	122.05	113.58	122.07	123.63	133.54	111.18	87.37	87.07
SF_6	6.35	8.23	9.75	7.40	5.17	6.04	5.29	5.20	5.31	5.07	5.22	5.36	5.16	5.09	5.07	5.09	5.03	5.03	5.05
Total	**136,747.56**	**133,269.72**	**135,883.30**	**132,518.61**	**125,326.40**	**119,233.58**	**116,256.84**	**113,007.78**	**103,354.44**	**99,937.24**	**96,072.75**	**92,397.52**	**96,246.21**	**93,010.74**	**86,306.12**	**75,874.08**	**78,013.11**	**77,769.87**	**71,934.67**
B. GHG emissions/removals from LULUCF																			
CO_2	-3,576.62	-3,651.81	-2,577.83	-3,409.08	-3,509.49	-3,444.94	-3,555.50	-3,626.28	-2,590.28	-2,031.84	-3,498.27	-4,101.31	-3,836.82	-4,680.12	-5,187.96	-5,182.56	-5,224.13	-5,259.76	-4,677.36
CH_4 in kt	0.42	0.84	12.85	1.74	1.85	0.66	0.71	1.75	0.64	0.38	0.43	1.27	0.74	0.78	3.11	0.75	5.49	2.22	19.05
N_2O in kt	0.05	0.06	0.14	0.07	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.07	0.05	0.09	0.06	0.15
Total	**-3,551.69**	**-3,613.71**	**-2,180.56**	**-3,342.41**	**-3,439.29**	**-3,410.99**	**-3,520.49**	**-3,560.11**	**-2,557.62**	**-2,007.41**	**-3,472.35**	**-4,050.74**	**-3,802.04**	**-4,644.11**	**-5,082.41**	**-5,147.27**	**-5,046.51**	**-5,180.49**	**-4,103.01**
C. GHG Emissions from International Transport																			
CO_2	21,333.01	22,004.63	22,639.51	21,938.64	24,796.63	22,045.52	19,771.67	16,465.15	16,246.67	16,267.32	16,801.61	17,129.16	16,901.36	17,129.03	17,540.52	15,096.29	16,478.75	16,478.75	21,333.01
CH_4 in kt	136.69	134.34	128.34	120.41	114.73	121.33	105.59	79.91	89.94	88.07	89.35	81.69	82.22	79.59	77.87	66.06	72.16	72.16	72.16
N_2O in kt	351.01	374.27	363.07	355.02	319.70	280.80	216.54	178.59	165.97	176.04	191.34	207.55	211.29	216.27	218.73	178.57	200.81	465.81	730.81
Total	**21,820.72**	**22,513.24**	**23,130.92**	**22,414.08**	**25,231.06**	**22,447.65**	**20,093.80**	**16,723.65**	**16,502.58**	**16,531.42**	**17,082.30**	**17,418.41**	**17,194.88**	**17,424.89**	**17,837.12**	**15,340.92**	**16,751.72**	**17,016.72**	**17,281.72**

2.2 Description and interpretation of emission trends by category

GHG emissions trends by sector for the period 1990 – 2023 are presented in ***Table 2.2***.

Emissions from *Energy* in 2023 ***(Figure 2.1)*** accounted for 67.63% of total GHG emissions (without LULUCF) and decreased by approximately 36.93% compared to 1990 levels.

The living standards improvement, due to the economic growth, the important growth of the services sector and the introduction of natural gas in the Greek energy system represent the basic factors affecting emissions trends from Energy for the period 1990 – 2007. A reduction of emissions is observed by 41.9% in 2019 compared to 2008, due to the economic recession at the beginning of the period, but also due to measures as the increase of RES and NG share of the energy mixture, along with energy efficiency improvement actions. In addition, the high decrease in 2020 compared to 2019 is mainly attributed to the significant reduction of the operation of lignite-fired plants, which were replaced by higher share of NG and renewables compared to previous years, and the COVID-19 restrictions in transport sector. According to the NECP of Greece, there is an undergoing plan for the phasing-out of all but one lignite-plants by 2023. The remaining plant will be converted to NG by 2028. GHG emissions have increased by 5.5% in 2022 compared to 2020, which is attributed to the removal of COVID-19 confinement measures, but decreased by 10.7% in 2023 compared to 2022.

The living standards improvement resulted in an increase of energy consumption and particularly electricity consumption (mainly in the residential – tertiary sector), passenger cars ownership and transportation activity. The increase of electricity consumption led not only to the increase of direct emissions (due to combustion for electricity generation) but also of fugitive methane emissions from lignite mining. At the same time total CO2 emissions per electricity produced have decreased mainly as a result of the introduction of natural gas and RES into the electricity system. It should be mentioned that the availability of hydropower has a significant effect to emissions trends. For instance, the significant increase of electricity demand in 1999 was not followed by a similar increase of emissions because of the penetration of natural gas and the high availability of hydropower. It should be also mentioned that up to 1996 supply of natural gas was exclusively minor quantities from domestic primary production. In essence, the introduction of natural gas in the Greek energy system started in 1997 and since then its consumption has been continuously increasing.

The majority of GHG emissions (43.1%) in 2023 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 36.1%, 8.9% and 10.4% respectively. The rest 0.8% and 0.7% of total GHG emissions from Energy derived from fugitive emissions from fuels and other (mobile).

Within the fuel combustion activities, the only sector with increased emissions compared to 1990 is transport, showing an increase of 20.92%. It should be noted that GHG emissions from transport were reduced by 14% in 2020 compared to 2019 at a significant share due to COVID-19 restrictions, but in 2022 they have recovered their 2019 levels. Emissions from manufacturing industries and construction, energy industries and other sectors (i.e. residential, tertiary and

agriculture sectors) had decreased by around 53.75%, 51.55% and 41.26%, respectively, compared to 1990. The decrease in the other sectors (i.e. residential, tertiary and agriculture sectors) is noticeable during the recent years, with the exception of 2020 compared to 2019, where the increase of emissions is attributed to a significant share of the COVID-19 restrictions in transport. Finally, fugitive emissions from fuels decreased by 71.10% for the period 1990 – 2023, due to the reduction of the use of lignite for power production.

Emissions from Industrial Processes and Product use in 2023 accounted for 12.67% of the total emissions (excluding LULUCF) and decreased by 16.64% compared to 1990 levels. Emissions from IPPU are characterized by intense fluctuations during the period 1990 – 2023 reaching a minimum value of 9.11 Mt CO2 eq in 2023 and a maximum value of 15.25 Mt CO2 eq in 1999. The low value for 2023 is directly related to the fact that many industries have ceased their operation, whereas the maximum value is attributed to changes in industrial production and especially in HCFC-22 production. It should be noted that had it not been for the consumption of f-gases subcategory, the decrease of the recent years would have been much deeper.

Emissions from Agriculture, that accounted for 11.08% of total emissions in 2023 (without LULUCF), decreased by approximately 24.35% compared to 1990 levels. Emissions reduction is mainly due to the reduction of N2O emissions from agricultural soils, because of the reduction in the use of synthetic nitrogen fertilizers and animal population. The decrease in the use of synthetic nitrogen fertilizers is attributed to the increase of organic farming, the high price of fertilizers and the impact of initiatives to promote good practice in fertilizer use. The changes of the rest determining parameters of GHG emissions from the sector (e.g. crops production etc.) have a minor effect on GHG emissions trend.

Emissions from the Waste Sector (8.62% of the total emissions, without LULUCF), increased by approximately 15.15% from 1990. Living standards improvement resulted in an increase of the generated waste and thus of emissions since 1990. However, the increase of recycling along with the exploitation of the biogas produced limits the increase of methane emissions. At the same time, emissions from wastewater handling have considerably decreased, due to the continuous increase of the population served by aerobic wastewater handling facilities.

The Land Use, Land-Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2023. The sink capacity of the LULUCF sector fluctuates between -2 Mt CO2 eq. and -5.18 Mt CO2 eq., showing fluctuations in trend. This is the result of the increase of the sink capacity of the Forest Land, Grassland and Cropland category.

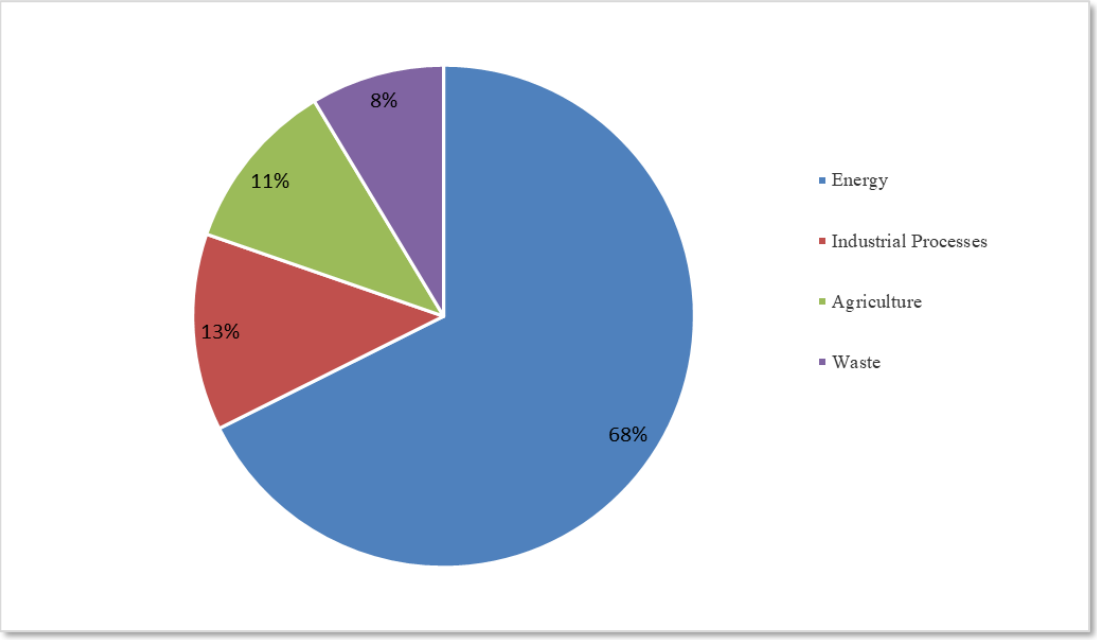


Figure 2.1 ***Relative contribution of activity sectors to total GHG emissions (without LULUCF) in 2023***

Table 2.2a Total GHG emissions (in kt CO2 eq) by sector for the period 1990-2004

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Energy	77,133.43	77,246.16	79,228.42	78,870.98	81,109.57	81,174.63	83,395.36	87,928.58	92,652.89	92,091.99	96,890.77	99,346.16	99,208.74	103,085.36	103,538.52
IPPU	10,933.61	10,855.35	10,322.46	10,642.69	11,130.89	12,818.42	13,470.98	13,908.39	14,550.68	15,245.64	14,281.94	13,797.22	13,972.53	13,832.46	13,989.37
Agriculture	10,534.68	10,548.85	10,271.49	9,791.13	9,524.15	9,887.56	9,938.03	9,865.49	9,822.21	9,734.57	9,563.76	9,536.74	9,537.18	9,512.85	9,541.09
Waste	5,383.97	5,355.96	5,465.31	5,523.23	5,693.00	5,700.53	5,811.52	5,767.99	5,967.92	5,913.69	5,922.97	5,050.84	5,000.78	5,138.40	5,145.92
Total (1)	**103,985.69**	**104,006.32**	**105,287.68**	**104,828.03**	**107,457.62**	**109,581.14**	**112,615.89**	**117,470.44**	**122,993.71**	**122,985.88**	**126,659.44**	**127,730.96**	**127,719.22**	**131,569.08**	**132,214.90**
LULUCF	**-2,279.61**	**-2,412.13**	**-2,604.37**	**-3,089.61**	**-2,827.54**	**-3,078.82**	**-2,400.45**	**-2,196.63**	**-2,220.27**	**-2,744.08**	**-2,523.73**	**-2,646.56**	**-2,992.17**	**-2,743.79**	**-2,722.39**
Index per sector															
Energy	100.00	100.15	102.72	102.25	105.15	105.24	108.12	114.00	120.12	119.39	125.61	128.80	128.62	133.65	134.23
IPPU	100.00	99.28	94.41	97.34	101.80	117.24	123.21	127.21	133.08	139.44	130.62	126.19	127.79	126.51	127.95
Agriculture	100.00	100.13	97.50	92.94	90.41	93.86	94.34	93.65	93.24	92.40	90.78	90.53	90.53	90.30	90.57
Waste	100.00	99.48	101.51	102.59	105.74	105.88	107.94	107.13	110.85	109.84	110.01	93.81	92.88	95.44	95.58
Total (2)	**100.00**	**100.02**	**101.25**	**100.81**	**103.34**	**105.38**	**108.30**	**112.97**	**118.28**	**118.27**	**121.80**	**122.84**	**122.82**	**126.53**	**127.15**

1) Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

2) *Land Use, Land Use Change and Forestry* is not included

Table 2.2b Total GHG emissions (in kt CO2 eq) by sector for the period 2005-2023

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Energy	107,379.67	106,056.84	108,314.44	105,412.56	100,450.70	93,261.20	92,161.13	88,474.05	78,070.49	74,616.79	71,299.97	67,043.04	70,348.04	67,389.30	61,298.69	51,598.40	53,552.06	54,453.19	48,650.80
IPPU	14,774.64	12,522.30	12,924.61	12,712.27	10,977.42	11,433.82	10,044.06	10,855.73	11,571.53	11,937.56	11,579.42	12,087.35	12,382.11	11,991.49	11,344.36	10,170.87	9,997.43	9,126.21	9,114.57
Agriculture	9,337.32	9,244.70	9,368.95	9,092.01	8,881.73	9,198.69	8,965.32	8,839.48	8,754.65	8,347.14	8,165.96	8,157.39	8,189.34	8,121.04	8,100.53	8,421.27	8,356.22	7,976.39	7,969.54
Waste	5,255.93	5,445.89	5,275.30	5,301.77	5,016.55	5,339.87	5,086.33	4,838.53	4,957.77	5,035.75	5,027.39	5,109.74	5,326.72	5,508.91	5,562.53	5,683.54	6,107.40	6,214.07	6,199.77
Total (1)	**136,747.56**	**133,269.72**	**135,883.30**	**132,518.61**	**125,326.40**	**119,233.58**	**116,256.84**	**113,007.78**	**103,354.44**	**99,937.24**	**96,072.75**	**92,397.52**	**96,246.21**	**93,010.74**	**86,306.12**	**75,874.08**	**78,013.11**	**77,769.87**	**71,934.67**
LULUCF	**-3,551.69**	**-3,613.71**	**-2,180.56**	**-3,342.41**	**-3,439.29**	**-3,410.99**	**-3,520.49**	**-3,560.11**	**-2,557.62**	**-2,007.41**	**-3,472.35**	**-4,050.74**	**-3,802.04**	**-4,644.11**	**-5,082.41**	**-5,147.27**	**-5,046.51**	**-5,180.49**	**-4,103.01**
Index per sector																			
Energy	139.21	137.50	140.42	136.66	130.23	120.91	119.48	114.70	101.21	96.74	92.44	86.92	91.20	87.37	79.47	66.89	69.43	70.60	63.07
IPPU	135.13	114.53	118.21	116.27	100.40	104.58	91.86	99.29	105.83	109.18	105.91	110.55	113.25	109.68	103.76	93.02	91.44	83.47	83.36
Agriculture	88.63	87.75	88.93	86.31	84.31	87.32	85.10	83.91	83.10	79.23	77.52	77.43	77.74	77.09	76.89	79.94	79.32	75.72	75.65
Waste	97.62	101.15	97.98	98.47	93.18	99.18	94.47	89.87	92.08	93.53	93.38	94.91	98.94	102.32	103.32	105.56	113.44	115.42	115.15
Total (2)	**131.51**	**128.16**	**130.68**	**127.44**	**120.52**	**114.66**	**111.80**	**108.68**	**99.39**	**96.11**	**92.39**	**88.86**	**92.56**	**89.45**	**83.00**	**72.97**	**75.02**	**74.79**	**69.18**

1) Emissions / removals from *Land Use, Land Use Change and Forestry* are not included in national totals

2) *Land Use, Land Use Change and Forestry* is not included

2.3 Description and interpretation of emission trends by gas

2.3.1 Carbon dioxide

Total CO2 emissions decreased from 83.44 Mt in 1990 to 51.99 Mt in 2023 (without LULUCF). The decrease of 31.05% from 1990 to 2023 follows the trends of energy sector.

CO2 emissions from Energy decreased, from 74.68 Mt in 1990 to 47.55 Mt in 2023, presenting a total decrease of 28.72% from 1990 to 2022. Carbon dioxide emissions from Industrial processes and product use in 2023 decreased by 41.65% compared to 1990 levels (***Figure 2.2***).

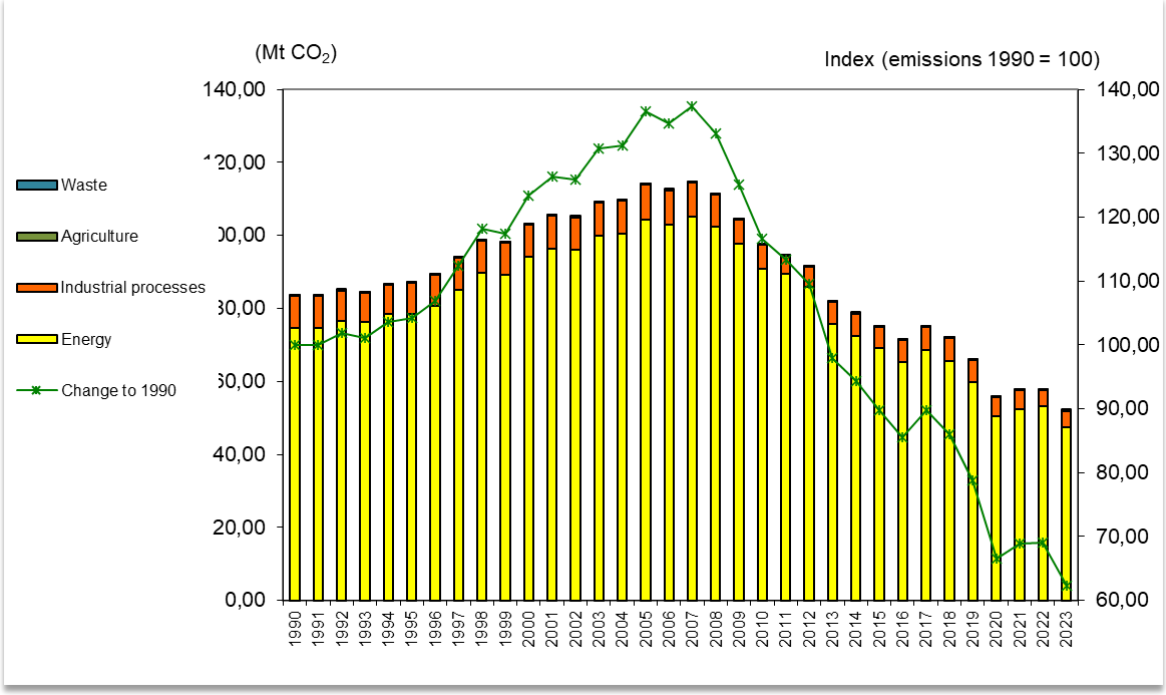


Figure 2.2 ***CO2 emissions by sector (in Mt) for the years 1990 – 2023 (without LULUCF)***

Table 2.3a CO2 emissions / removals by sector for the period 1990-2004 (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total (without LULUCF)	**83438.04**	**83407.50**	**84975.66**	**84284.96**	**86430.25**	**86963.21**	**89114.95**	**93801.54**	**98621.80**	**97934.81**	**102973.18**	**105361.88**	**105000.51**	**109066.72**	**109485.27**
Total (with LULUCF)	**81082.49**	**80956.17**	**82258.99**	**81094.03**	**83507.49**	**83828.06**	**86677.98**	**91529.96**	**96206.83**	**95169.1**	**100192.85**	**102672.32**	**101993.45**	**106305.5**	**106734.86**
Energy	**74677.03**	**74744.65**	**76672.13**	**76305.99**	**78476.95**	**78524.10**	**80680.93**	**85190.99**	**89775.62**	**89184.38**	**94014.56**	**96368.86**	**96112.64**	**100015.49**	**100448.11**
A. Fuel combustion	74634.33	74701.49	76635.83	76276.52	78451.18	78501.55	80655.97	85168.34	89760.01	89183.53	94000.59	96359.04	96103.01	100008.47	100441.26
1. Energy industries	43093.70	41932.61	44212.55	44111.98	46089.07	44857.20	44037.52	47473.14	49995.24	50294.82	54739.01	55254.97	54678.66	55921.54	57238.34
2. Man. Industry and Construction	9338.49	9387.80	9044.66	8760.33	8610.16	9481.90	10087.60	10194.95	10152.18	9139.77	9847.74	9971.73	9426.05	9102.77	8618.35
3. Transport	14136.62	14932.09	15294.12	15460.88	15753.14	16084.99	16535.05	17236.86	18998.77	19311.12	18364.24	19227.92	19553.34	20628.46	21024.82
4. Other sectors	8065.52	8449.00	8084.51	7943.33	7998.81	8077.46	9995.79	10263.39	10613.82	10437.82	11049.60	11904.42	12444.96	14355.70	13559.75
5. Other	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
B. Fugitive emissions	42.70	43.16	36.30	29.47	25.77	22.55	24.96	22.65	15.61	0.85	13.97	9.83	9.63	7.03	6.85
IPPU	**8700.38**	**8604.50**	**8247.75**	**7935.01**	**7912.33**	**8393.86**	**8387.78**	**8566.59**	**8802.07**	**8708.46**	**8919.93**	**8955.75**	**8851.34**	**9015.18**	**8999.78**
A. Mineral Industry	6775.42	6696.57	6775.95	6730.23	6702.71	7186.11	7176.79	7255.62	7294.80	7285.26	7492.72	7549.59	7312.46	7348.96	7357.01
B. Chemical Industry	680.65	649.65	248.00	170.01	30.43	32.03	33.38	116.18	382.22	353.33	281.96	135.77	165.68	286.61	304.52
C. Metal Industry	1012.06	1049.90	999.29	814.52	979.88	1006.90	1014.44	1040.52	986.21	918.40	1000.98	1111.55	1239.97	1239.99	1182.25
D. Non-energy products from fuels and solvent use	129.78	102.66	120.57	119.39	102.66	78.27	74.14	64.49	47.98	55.05	50.34	63.90	41.74	44.53	58.59
G. Other product manufacture and use	102.47	105.72	103.93	100.86	96.65	90.56	89.04	89.77	90.86	96.42	93.93	94.93	91.49	95.09	97.41
Agriculture	**60.41**	**58.13**	**55.57**	**43.74**	**40.75**	**45.02**	**46.02**	**43.74**	**43.88**	**41.75**	**38.47**	**37.04**	**36.05**	**35.19**	**36.33**
LULUCF	**-2,355.55**	**-2,451.33**	**-2,716.68**	**-3,190.93**	**-2,922.76**	**-3,135.14**	**-2,436.97**	**-2,271.58**	**-2,414.96**	**-2,765.71**	**-2,780.33**	**-2,689.55**	**-3,007.06**	**-2,761.21**	**-2,750.41**
Waste	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.22**	**0.48**	**0.85**	**1.05**
International transport [1)]	**10580.51**	**9569.44**	**10762.45**	**12332.40**	**13393.29**	**14004.40**	**12530.32**	**12475.75**	**13767.30**	**12829.23**	**14018.48**	**13513.65**	**12342.00**	**13304.19**	**13474.19**
Aviation	2474.79	2133.99	2226.36	2369.69	2812.41	2637.23	2525.76	2442.94	2563.98	2879.30	2525.76	2347.31	2347.39	3055.51	3140.94
Marine	8105.72	7435.45	8536.09	9962.71	10580.88	11367.17	10004.56	10032.81	11203.32	9949.93	11492.72	11166.34	9994.61	10248.68	10333.25

Emissions from International transport are not included in national totals.

Table 2.3b CO2 emissions / removals by sector for the period 2005-2023 (in kt)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total (without LULUCF)	**113888.96**	**112419.55**	**114545.69**	**111080.35**	**104319.84**	**97354.14**	**94505.22**	**91392.59**	**81713.25**	**78635.69**	**74926.67**	**71359.61**	**74841.75**	**71778.09**	**65736.32**	**55576.93**	**57527.91**	**57686.06**	**51988.22**
Total (with LULUCF)	**110312.33**	**108767.74**	**111967.85**	**107671.27**	**100810.34**	**93909.20**	**90949.71**	**87766.32**	**79122.97**	**76603.85**	**71428.39**	**67258.30**	**71004.94**	**67097.97**	**60548.36**	**50394.37**	**52303.79**	**52349.29**	**47310.87**
Energy	**104267.84**	**103028.37**	**105251.03**	**102436.27**	**97642.73**	**90718.51**	**89550.85**	**85903.15**	**75823.30**	**72452.42**	**69217.26**	**65351.86**	**68489.20**	**65580.81**	**59762.67**	**50461.16**	**52409.29**	**53226.59**	**47549.84**
A. Fuel combustion	104262.25	103022.75	105246.45	102432.72	97638.29	90712.54	89545.61	85898.19	75819.23	72448.68	69213.62	65342.49	68481.49	65569.84	59753.63	50455.99	52405.77	53224.53	47546.76
1. Energy industries	58058.17	55895.54	59371.47	58019.05	54480.47	52036.60	53838.38	54507.26	49205.02	45784.63	40776.46	36,909.61	39,817.11	38,149.03	31,885.66	24,428.77	25,420.11	24,682.38	20,905.92
2. Man. Industry and Construction	10134.37	10369.07	9959.13	9325.77	7436.78	6813.24	4917.03	5457.78	5229.16	5397.33	5166.28	5,291.92	5,715.97	5,048.80	4,568.50	4,405.52	4,779.79	4,396.19	4,298.52
3. Transport	21333.01	22004.63	22639.51	21938.64	24796.63	22045.52	19771.67	16465.15	16246.67	16267.36	16801.61	17,129.16	16,901.58	17,129.04	17,519.81	15,040.88	16,439.59	17,622.64	17,253.00
4. Other sectors	14214.11	14104.93	12729.20	12453.05	10674.72	9574.70	10802.99	9257.07	4903.11	4810.77	6262.95	5,812.76	5,864.53	5,119.81	5,645.59	6,284.91	5,730.62	6,224.32	4,741.36
5. Other	522.59	648.58	547.15	696.21	249.69	242.49	215.53	210.93	235.28	188.58	206.32	199.05	182.30	123.17	134.07	295.90	35.67	298.99	347.95
B. Fugitive emissions	5.59	5.62	4.57	3.55	4.44	5.97	5.24	4.95	4.07	3.75	3.64	9.37	7.71	10.97	9.04	5.17	3.52	2.06	3.08
IPPU	**9587.22**	**9358.85**	**9257.86**	**8611.76**	**6639.74**	**6598.92**	**4922.91**	**5460.97**	**5860.11**	**6155.15**	**5680.51**	**5976.73**	**6314.16**	**6160.59**	**5935.45**	**5074.98**	**5076.47**	**4347.59**	**4403.36**
A. Mineral Industry	7926.76	7635.81	7471.57	6957.90	5321.32	4920.64	3108.56	3738.17	4170.20	4359.38	3956.73	4,271.67	4,246.72	4,007.64	3,931.48	3,368.88	3,621.15	3,342.85	3,381.08
B. Chemical Industry	296.92	313.93	317.94	338.06	453.25	632.88	584.38	502.02	516.91	569.38	495.05	461.93	804.62	951.19	877.74	845.53	679.42	310.48	448.68
C. Metal Industry	1215.54	1233.61	1301.47	1167.74	732.63	909.44	1101.46	1100.61	1049.74	1097.03	1098.74	1,112.68	1,128.61	1,062.81	970.86	712.58	632.07	541.56	413.72
D. Non-energy products from fuels and solvent use	53.23	79.72	70.18	53.85	41.91	42.60	40.37	34.90	37.10	46.02	46.18	46.45	49.44	51.88	68.47	59.93	55.66	64.47	71.40
G. Other product manufacture and use	94.77	95.78	96.70	94.20	90.62	93.36	88.13	85.27	86.16	83.33	83.81	84.00	84.77	87.07	86.90	88.05	88.16	88.23	88.48
Agriculture	**31.91**	**29.92**	**33.62**	**28.64**	**24.93**	**30.35**	**25.84**	**25.00**	**26.01**	**23.64**	**23.41**	**26.36**	**34.14**	**32.91**	**34.80**	**37.22**	**38.29**	**30.71**	**30.77**
LULUCF	**-3576.62**	**-3651.81**	**-2577.83**	**-3409.08**	**-3509.49**	**-3444.94**	**-3555.50**	**-3626.28**	**-2590.28**	**-2031.84**	**-3498.27**	**-4101.31**	**-3836.82**	**-4680.12**	**-5187.96**	**-5182.56**	**-5224.13**	**-5259.76**	**-4677.36**
Waste	**1.98**	**2.41**	**3.17**	**3.68**	**12.43**	**6.36**	**5.61**	**3.48**	**3.83**	**4.48**	**5.48**	**4.66**	**4.26**	**3.78**	**3.40**	**3.57**	**3.87**	**4.16**	**4.26**
International transport 1)	**11815.09**	**12727.53**	**13103.79**	**12862.32**	**11147.83**	**11373.02**	**11652.07**	**9727.87**	**9382.76**	**8878.27**	**8657.30**	**8664.83**	**10387.72**	**10982.01**	**12211.00**	**6661.29**	**8436.40**	**10317.33**	**10710.56**
Aviation	2600.48	2779.42	2948.31	2930.90	2717.91	2584.15	2696.04	2386.98	2466.45	2829.92	2869.09	3,079.15	3,434.92	3,858.57	3,988.90	1,323.54	2,511.64	3,941.75	4,165.60
Marine	9214.61	9948.11	10155.48	9931.42	8429.92	8788.87	8956.03	7340.89	6916.31	6048.35	5788.21	5,585.68	6,952.81	7,123.44	8,222.09	5,337.76	5,924.76	6,375.58	6,544.95

1) Emissions from International transport are not included in national totals.

2.3.2 Methane

The trend of methane emissions from 1990 to 2023 by source category is presented in ***Table 2.4*** and in ***Figure 2.3***. In 2023 emissions presented a decrease comparing to 1990 values by 7% (without LULUCF).

Waste represents the largest anthropogenic source of methane emissions in Greece accounting for 50.42% of total methane emissions in 2023 (without LULUCF). Methane emissions from Waste increased by 15.58% since 1990 and are mainly attributed to Solid Waste Disposal on Land and Wastewater Handling.

Methane emissions from Agriculture in 2023 decreased by 12.15% compared to 1990 levels. Methane emissions from Agriculture, with enteric fermentation being the main source category in the sector, in 2023 accounted for 42.27% of total methane emissions. Methane emissions from the Energy sector (mainly fugitive emissions from coal mining and production, processing, and distribution of liquid fuels and natural gas) account for almost the remaining 6.28% of the total methane emissions. Finally, the contribution of CH4 emissions from Iron and Steel Production can be considered negligible.

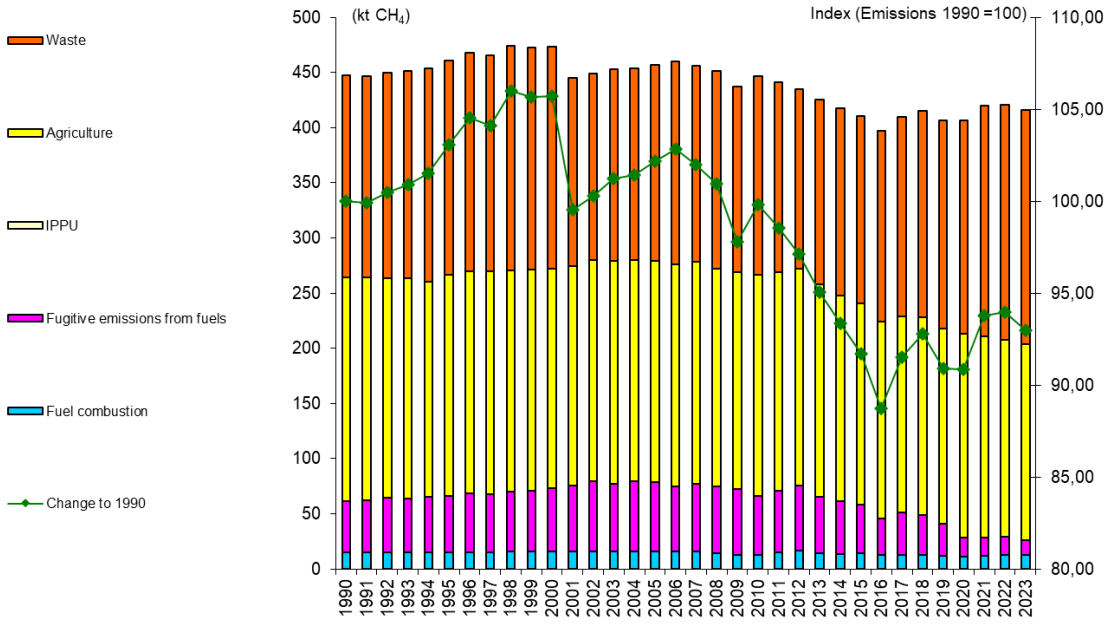


Figure 2.3 ***CH4 emissions by sector (in kt) for the period 1990 – 2023 (without LULUCF)***

Table 2.4a CH4 emissions by source category for the period 1990-2004 (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total (without LULUCF)	**447.38**	**446.92**	**449.59**	**451.41**	**454.09**	**461.18**	**467.61**	**465.77**	**474.27**	**472.78**	**473.02**	**445.35**	**448.76**	**452.89**	**453.83**
Total (with LULUCF)	**449.89**	**448.17**	**453.27**	**454.68**	**457.14**	**462.92**	**468.66**	**468.08**	**480.58**	**473.26**	**481.34**	**446.47**	**448.91**	**453.11**	**454.37**
Energy	**61.67**	**62.48**	**64.34**	**63.91**	**65.39**	**66.26**	**68.33**	**67.78**	**70.20**	**71.17**	**73.63**	**75.75**	**79.29**	**77.54**	**79.33**
A. Fuel combustion	15.01	15.18	15.11	15.14	15.13	15.17	15.26	15.42	15.51	15.50	15.71	15.79	15.62	15.56	15.62
1. Energy industries	0.57	0.57	0.58	0.59	0.60	0.61	0.60	0.63	0.65	0.66	0.73	0.72	0.72	0.75	0.74
2. Manufacturing industry and Construction	0.49	0.48	0.48	0.46	0.45	0.48	0.51	0.51	0.49	0.47	0.53	0.52	0.53	0.47	0.47
3. Transport	4.42	4.46	4.41	4.46	4.45	4.50	4.52	4.60	4.76	4.89	4.92	5.05	4.98	4.95	4.99
4. Other sectors	9.54	9.67	9.64	9.63	9.62	9.59	9.64	9.68	9.60	9.47	9.52	9.50	9.39	9.40	9.41
B. Fugitive emissions from fuels	46.66	47.30	49.23	48.77	50.27	51.09	53.06	52.37	54.69	55.67	57.93	59.96	63.67	61.98	63.71
1. Solid fuels	45.20	45.90	47.95	47.75	49.36	50.22	52.07	51.25	53.03	54.05	55.65	57.79	61.38	59.49	61.01
2. Oil and natural gas	1.46	1.40	1.28	1.02	0.90	0.86	0.99	1.11	1.66	1.62	2.28	2.18	2.29	2.50	2.70
IPPU	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.06**	**0.07**	**0.06**	**0.06**	**0.03**	**0.02**	**0.01**	**0.02**	**0.02**	**0.02**
Agriculture	**202.28**	**202.12**	**199.14**	**199.36**	**194.68**	**200.72**	**201.15**	**201.56**	**200.49**	**200.37**	**198.25**	**199.12**	**200.68**	**202.01**	**200.90**
A. Enteric fermentation	164.39	164.64	161.81	160.62	156.13	161.42	161.54	161.65	161.28	162.34	160.80	162.06	163.41	164.75	163.59
B. Manure management	33.53	33.44	33.36	33.68	32.80	33.12	32.92	33.12	32.99	32.43	32.50	31.88	31.81	31.78	31.79
C. Rice cultivation	3.29	2.95	2.94	4.05	4.74	5.22	5.72	5.82	5.25	4.67	3.98	4.22	4.48	4.52	4.55
F. Field burning of agricultural residues	1.06	1.09	1.03	1.01	1.00	0.96	0.98	0.98	0.96	0.94	0.97	0.96	0.97	0.97	0.98
LULUCF	**2.51**	**1.24**	**3.67**	**3.28**	**3.06**	**1.74**	**1.05**	**2.31**	**6.31**	**0.48**	**8.32**	**1.12**	**0.15**	**0.21**	**0.54**
Waste	**183.39**	**182.26**	**186.05**	**188.08**	**193.96**	**194.15**	**198.07**	**196.36**	**203.53**	**201.21**	**201.11**	**170.46**	**168.78**	**173.31**	**173.58**
A. Solid waste disposal	89.72	92.46	95.40	98.50	101.81	105.30	108.97	112.85	116.90	121.06	126.02	109.26	114.19	122.39	124.56
B. Biological treatment of solid waste	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.15	0.14	0.14	0.14	0.03	0.03	0.02	0.02
C. Incineration and open burning of waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Waste water treatment and discharge	93.65	89.79	90.62	89.54	92.11	88.81	89.07	83.35	86.49	80.01	74.96	61.17	54.55	50.90	49.00
International Transport 1)	**0.68**	**0.61**	**0.70**	**0.82**	**0.87**	**0.92**	**0.82**	**0.82**	**0.93**	**0.83**	**0.96**	**0.94**	**0.85**	**0.88**	**0.89**
Aviation	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Marine	0.66	0.60	0.68	0.80	0.85	0.90	0.80	0.80	0.91	0.81	0.94	0.92	0.83	0.86	0.87

1) Emissions from International Transport are not included in national totals

Table 2.4b CH4 emissions by source category for the period 2005-2023 (in kt)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total (without LULUCF)	**457.09**	**460.10**	**456.33**	**451.56**	**437.57**	**446.62**	**440.87**	**434.65**	**425.16**	**417.76**	**410.23**	**396.92**	**409.38**	**415.06**	**406.77**	**406.44**	**419.66**	**420.32**	**416.08**
Total (with LULUCF)	**457.51**	**460.94**	**469.18**	**453.30**	**439.42**	**447.27**	**441.59**	**436.40**	**425.80**	**418.14**	**410.66**	**398.19**	**410.12**	**415.84**	**409.87**	**407.19**	**425.15**	**422.54**	**435.13**
Energy	**79.00**	**74.99**	**77.56**	**75.09**	**72.84**	**66.26**	**70.71**	**75.64**	**65.40**	**61.67**	**58.34**	**45.38**	**50.88**	**49.01**	**40.90**	**28.51**	**28.39**	**29.41**	**26.42**
A. Fuel combustion	15.65	15.50	16.01	13.98	12.67	13.08	14.92	16.39	14.39	13.85	14.26	12.69	12.91	12.40	12.08	11.05	11.90	12.37	12.61
1. Energy industries	0.77	0.77	0.82	0.82	0.72	0.66	0.67	0.67	0.63	0.59	0.55	0.54	0.58	0.55	0.51	0.43	0.45	0.45	0.40
2. Manufacturing industry and Construction	0.57	0.54	0.52	0.56	0.49	0.47	0.45	0.37	0.26	0.31	0.35	0.29	0.32	0.36	0.37	0.40	0.41	0.41	0.42
3. Transport	4.88	4.80	4.58	4.30	4.10	4.33	3.77	2.85	3.21	3.05	2.95	2.80	2.72	2.72	2.67	2.20	2.43	2.49	2.34
4. Other sectors	9.42	9.39	10.08	8.29	7.37	7.62	10.02	12.50	10.28	9.90	10.40	9.06	9.28	8.77	8.53	8.03	8.61	9.02	9.44
B. Fugitive emissions from fuels	63.35	59.48	61.55	61.11	60.16	53.18	55.79	59.25	51.01	47.82	44.09	32.69	37.98	36.60	28.82	17.46	16.48	17.04	13.82
1. Solid fuels	60.45	56.20	57.89	57.24	56.52	49.23	51.10	54.83	46.97	44.29	40.28	28.43	32.86	31.78	23.84	12.24	10.80	12.41	9.38
2. Oil and natural gas	2.91	3.29	3.66	3.87	3.64	3.95	4.70	4.41	4.04	3.53	3.81	4.26	5.11	4.82	4.98	5.22	5.68	4.63	4.43
IPPU	**0.02**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**	**0.01**
Agriculture	**200.43**	**200.81**	**200.78**	**197.33**	**196.09**	**200.09**	**198.65**	**196.21**	**192.67**	**186.14**	**182.16**	**178.90**	**178.19**	**179.40**	**177.28**	**184.40**	**182.68**	**178.44**	**177.69**
A. Enteric fermentation	163.03	164.36	163.85	161.06	159.67	163.36	162.34	160.45	158.24	152.81	149.08	145.62	144.91	146.45	144.87	151.72	150.20	147.56	147.14
B. Manure management	31.83	31.07	31.03	30.33	29.81	29.84	29.28	28.74	27.97	27.13	26.58	26.16	25.99	26.62	26.24	26.63	25.94	25.91	25.76
C. Rice cultivation	4.62	4.46	5.00	5.00	5.60	6.01	6.18	6.16	5.62	5.42	5.81	6.43	6.56	5.67	5.53	5.42	5.92	4.36	4.18
F. Field burning of agricultural residues	0.95	0.92	0.89	0.94	1.00	0.88	0.85	0.86	0.84	0.78	0.69	0.70	0.73	0.66	0.64	0.62	0.62	0.61	0.62
LULUCF	**0.42**	**0.84**	**12.85**	**1.74**	**1.85**	**0.66**	**0.71**	**1.75**	**0.64**	**0.38**	**0.43**	**1.27**	**0.74**	**0.78**	**3.11**	**0.75**	**5.49**	**2.22**	**19.05**
Waste	**177.64**	**184.28**	**177.96**	**179.12**	**168.63**	**180.25**	**171.49**	**162.80**	**167.09**	**169.94**	**169.71**	**172.63**	**180.28**	**186.64**	**188.58**	**193.52**	**208.57**	**212.46**	**211.96**
A. Solid waste disposal	132.77	138.30	136.98	141.49	132.39	140.41	131.87	123.85	127.64	130.37	129.99	130.38	135.19	139.74	139.49	145.40	157.65	160.77	159.65
B. Biological treatment of solid waste	0.07	0.33	0.36	0.37	0.12	0.55	0.72	0.94	0.91	0.80	0.77	1.25	1.82	2.42	2.71	2.52	2.82	3.70	4.22
C. Incineration and open burning of waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
D. Waste water treatment and discharge	44.80	45.64	40.62	37.27	36.11	39.28	38.90	38.01	38.54	38.77	38.95	40.99	43.28	44.49	46.38	45.60	48.10	47.99	48.09
International Transport 1)	**0.80**	**0.86**	**0.88**	**0.87**	**0.73**	**0.76**	**0.78**	**0.64**	**0.60**	**0.53**	**0.50**	**0.48**	**0.60**	**0.62**	**0.72**	**0.45**	**0.50**	**0.54**	**0.56**
Aviation	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.02	0.03	0.03
Marine	0.78	0.84	0.86	0.85	0.72	0.74	0.76	0.62	0.59	0.51	0.48	0.46	0.58	0.60	0.69	0.44	0.48	0.51	0.53

1) Emissions from International Transport are not included in national totals

2.3.3 Nitrous oxide

The trend of nitrous oxide emissions from 1990 to 2023 by source category is presented in ***Table 2.5*** and in ***Figure 2.4***.

Agriculture represents the largest anthropogenic source of nitrous oxide emissions in Greece (79.83% approximately of the total nitrous oxide emissions in 2023, without LULUCF). Emissions from this sector decreased by 38.40% since 1990, mainly because of new agricultural practices applied, affecting the use of synthetic nitrogen fertilizers.

Nitrous oxide is also produced from the reaction between nitrogen and oxygen during fossil fuel combustion. Nitrous oxide emissions from fossil fuels combustion (accounting for 9.73% of total nitrous oxide emissions in 2023) decreased by 50.50% from 1990 (without LULUCF).

Production of nitric acid is the major source of N2O emissions from Industrial processes and product use and accounts for 3.42% of total N2O emissions in 2023. Nitrous oxide emissions from this source decreased by 88.10% from 1990, due to the reduction of nitric acid production in Greece. N2O emissions from Waste in 2023 (7.02% of total emissions without LULUCF) increased by 4.75% compared to 1990 levels.

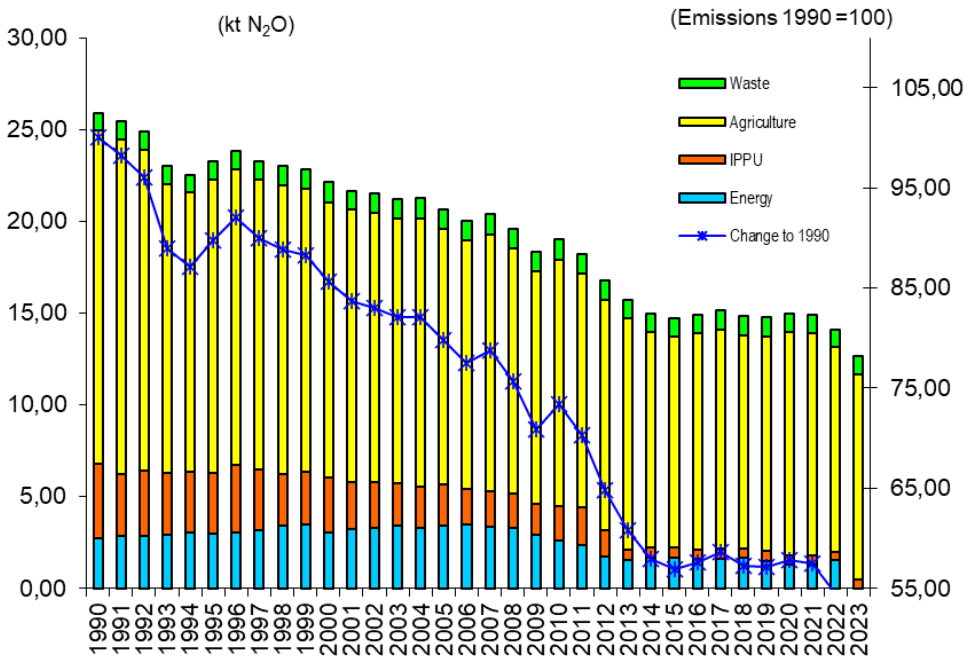


Figure 2.4 ***N2O emissions by sector (in kt) for the period 1990 – 2023 (without LULUCF)***

Table 2.5a N2O emissions by source category for the period 1990-2004 (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total (without LULUCF)	**25.87**	**25.42**	**24.86**	**23.00**	**22.54**	**23.23**	**23.81**	**23.27**	**22.99**	**22.82**	**22.14**	**21.66**	**21.49**	**21.22**	**21.24**
Total (with LULUCF)	**25.88**	**25.44**	**24.90**	**23.05**	**22.58**	**23.26**	**23.83**	**23.32**	**23.06**	**22.85**	**22.23**	**21.70**	**21.54**	**21.26**	**21.29**
Energy	**2.75**	**2.84**	**2.85**	**2.93**	**3.02**	**3.00**	**3.02**	**3.17**	**3.44**	**3.45**	**3.07**	**3.23**	**3.31**	**3.39**	**3.28**
A. Fuel combustion	2.75	2.84	2.85	2.93	3.02	3.00	3.02	3.17	3.44	3.45	3.07	3.23	3.31	3.39	3.28
1. Energy industries	0.49	0.47	0.50	0.50	0.52	0.50	0.49	0.53	0.56	0.55	0.59	0.60	0.59	0.60	0.61
2. Man. Industry and Construction	0.18	0.18	0.18	0.18	0.18	0.20	0.23	0.24	0.23	0.20	0.24	0.24	0.24	0.22	0.22
3. Transport	0.91	0.96	1.03	1.13	1.20	1.24	1.22	1.32	1.58	1.62	1.16	1.30	1.29	1.27	1.32
4. Other sectors	1.17	1.22	1.14	1.13	1.12	1.05	1.08	1.08	1.08	1.08	1.08	1.10	1.20	1.30	1.13
B. Fugitive emissions from fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IPPU	**4.02**	**3.40**	**3.54**	**3.39**	**3.31**	**3.30**	**3.71**	**3.32**	**2.82**	**2.91**	**2.97**	**2.57**	**2.50**	**2.34**	**2.25**
Agriculture	**18.15**	**18.23**	**17.51**	**15.72**	**15.22**	**15.93**	**16.07**	**15.77**	**15.72**	**15.41**	**15.00**	**14.81**	**14.65**	**14.42**	**14.64**
B. Manure management	1.26	1.27	1.24	1.24	1.16	1.21	1.21	1.21	1.21	1.20	1.20	1.18	1.19	1.19	1.21
D. Agricultural soils	16.86	16.93	16.24	14.45	14.03	14.70	14.84	14.53	14.48	14.18	13.77	13.60	13.44	13.20	13.40
F. Field burning of agr.. residues	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.03	0.03
LULUCF	**0.02**	**0.02**	**0.04**	**0.04**	**0.04**	**0.03**	**0.03**	**0.04**	**0.07**	**0.03**	**0.09**	**0.04**	**0.04**	**0.04**	**0.05**
Waste	**0.94**	**0.95**	**0.96**	**0.97**	**0.99**	**1.00**	**1.00**	**1.02**	**1.01**	**1.05**	**1.10**	**1.05**	**1.04**	**1.07**	**1.07**
International transport 1)	**0.86**	**0.84**	**1.04**	**1.15**	**1.27**	**1.47**	**1.22**	**1.21**	**1.23**	**1.15**	**1.23**	**1.06**	**0.96**	**0.92**	**0.90**
Aviation	0.07	0.06	0.06	0.07	0.08	0.07	0.07	0.07	0.07	0.08	0.07	0.07	0.07	0.09	0.09
Marine	0.79	0.78	0.98	1.08	1.19	1.40	1.15	1.14	1.16	1.07	1.16	0.99	0.89	0.83	0.81

1) Emissions from International transport are not included in national totals

Table 2.5b N2O emissions by source category for the period 2005-2023 (in kt)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total (without LULUCF)	**20.63**	**20.04**	**20.37**	**19.57**	**18.34**	**19.00**	**18.19**	**16.76**	**15.74**	**14.99**	**14.73**	**14.91**	**15.16**	**14.81**	**14.77**	**14.95**	**14.88**	**14.12**	**14.01**
Total (with LULUCF)	**20.69**	**20.10**	**20.51**	**19.64**	**18.41**	**19.06**	**18.25**	**16.82**	**15.80**	**15.04**	**14.78**	**14.97**	**15.22**	**14.86**	**14.84**	**15.00**	**14.97**	**14.18**	**14.15**
Energy	**3.40**	**3.51**	**3.37**	**3.30**	**2.90**	**2.59**	**2.38**	**1.71**	**1.57**	**1.65**	**1.69**	**1.59**	**1.64**	**1.65**	**1.47**	**1.28**	**1.31**	**1.52**	**1.36**
A. Fuel combustion	3.40	3.50	3.37	3.30	2.90	2.59	2.38	1.71	1.57	1.65	1.69	1.59	1.64	1.65	1.47	1.28	1.31	1.52	1.36
1. Energy industries	0.62	0.58	0.60	0.59	0.57	0.53	0.54	0.55	0.49	0.46	0.41	0.33	0.37	0.35	0.27	0.16	0.15	0.15	0.12
2. Man. Industry and Construction	0.29	0.31	0.30	0.32	0.29	0.25	0.19	0.20	0.17	0.23	0.25	0.21	0.21	0.23	0.14	0.13	0.13	0.25	0.14
3. Transport	1.32	1.41	1.37	1.34	1.21	1.06	0.82	0.67	0.63	0.67	0.72	0.78	0.79	0.81	0.81	0.65	0.74	0.82	0.82
4. Other sectors	1.15	1.19	1.08	1.03	0.83	0.75	0.83	0.28	0.27	0.29	0.31	0.26	0.26	0.26	0.25	0.33	0.29	0.29	0.27
B. Fugitive emissions from fuels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IPPU	**2.24**	**1.91**	**1.90**	**1.85**	**1.67**	**1.87**	**2.02**	**1.48**	**0.55**	**0.57**	**0.54**	**0.52**	**0.54**	**0.54**	**0.54**	**0.53**	**0.49**	**0.48**	**0.48**
Agriculture	**13.94**	**13.55**	**14.01**	**13.35**	**12.70**	**13.46**	**12.74**	**12.53**	**12.58**	**11.74**	**11.48**	**11.78**	**11.95**	**11.57**	**11.71**	**12.15**	**12.09**	**11.13**	**11.18**
B. Manure management	1.21	1.20	1.20	1.15	1.12	1.16	1.14	1.15	1.14	1.10	1.03	1.03	1.01	1.02	1.00	1.06	1.01	0.99	1.01
D. Agricultural soils	12.70	12.33	12.79	12.18	11.56	12.27	11.58	11.36	11.42	10.62	10.43	10.74	10.91	10.53	10.69	11.08	11.06	10.12	10.16
F. Field burning of agr. Residues	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LULUCF	**0.05**	**0.06**	**0.14**	**0.07**	**0.07**	**0.06**	**0.06**	**0.06**	**0.06**	**0.05**	**0.05**	**0.06**	**0.05**	**0.05**	**0.07**	**0.05**	**0.09**	**0.06**	**0.15**
Waste	**1.06**	**1.07**	**1.09**	**1.07**	**1.07**	**1.08**	**1.05**	**1.04**	**1.04**	**1.03**	**1.02**	**1.02**	**1.04**	**1.05**	**1.05**	**0.99**	**0.99**	**0.99**	**0.98**
International transport [1)]	**0.75**	**0.79**	**0.76**	**0.73**	**0.66**	**0.69**	**0.66**	**0.56**	**0.58**	**0.54**	**0.58**	**0.59**	**0.67**	**0.66**	**0.76**	**0.57**	**0.66**	**0.84**	**0.84**
Aviation	0.07	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07	0.08	0.08	0.09	0.10	0.11	0.11	0.04	0.07	0.11	0.12
Marine	0.68	0.71	0.68	0.64	0.58	0.62	0.58	0.50	0.51	0.46	0.50	0.50	0.57	0.55	0.65	0.53	0.59	0.73	0.72

1) Emissions from International transport are not included in national totals

2.3.4 Halocarbons and sulphur hexafluoride

HFCs and PFCs are chemical substances, the production of which aims mainly to the substitution of ozone depleting substances (see Montreal Protocol – 1987). HFC and PFC are not harmful to the stratospheric ozone layer and thus their emissions are not controlled by the above-mentioned Protocol. However, many of these substances, as well as SF_6, are powerful greenhouse gases; in addition, apart from being characterized by a high Global Warming Potential (GWP), these gases have extremely long atmospheric lifetimes, resulting in their essentially irreversible accumulation in the atmosphere. Especially sulphur hexafluoride is the most potent greenhouse gas according to the IPCC evaluation.

Emission estimates of these gases presented in ***Table 2.6*** originate from:

1. The production of HCFC-22 (emissions of HFC-23) and aluminium production (emissions of CF_4 and C_2F_6). HFC-23 emissions have been increasing steadily up to 1999 due to an equivalent increase in the production of HCFC-22, while PFC emissions from aluminium have dropped due to the control/reduction of the "anode effect" during the production process, since 1990 (with the exception of the period 1997 – 2000). Emissions in the years 2008-2020 show fluctuations that are mainly attributed to the production levels. HFC-23 emissions are reported as not occurring since 2006, due to the closure of the plant producing HCFC-22.
2. Manufacturing, operation and maintenance of refrigeration and air conditioning equipment. F-gases emissions increased significantly since 1995 (base year), mainly due to the increase of air conditioning equipment in the residential sector, the increasing trend of emissions from the commercial refrigeration and the introduction of new passenger cars with air-conditioning systems, but also due to substitution of CFCs, following the implementation of the Montreal Protocol, leading to an increase in the number of equipment operating with f-gases until the economic recession in 2009. In addition, the new regulations have already been applied in Greece, however, this category is mostly driven by the existing equipment that presents high emissions during its disposal.
3. Use of f-gases (mainly HFC-134a) in aerosol products. The main application regards the use of HFC-134a in metered dose inhalers, as provided by the National Organization of Medicines and plants of the sector. The increment in the MDIs emissions is important in the recent years, mainly due to the inclusion of new MDIs brands in the recent years. Other aerosol applications regard the use of HFC-134a by one company in Greece, according to data received by the Hellenic Aerosol Association.
4. Use of HFC-134a and HFC-152a in foam blowing since 2001, as reported by the four plants of the sector. Emissions show a peak in 2006, resulting from the use of f-gases by three of the plants in that particular year.
5. The use of SF_6 in the electricity transmission and distribution system of the Public Power Corporation of Greece. Emissions mainly derive from the use of SF_6 in the transmission system, as the equipment used by the distribution system and by the medium voltage Greek clients refers to sealed pressure systems, minimizing the possibility of SF_6 leakages.

6. Finally, the emissions from fire extinguishers, which follow a continuous increasing trend in the inventory years.

Table 2.6a Actual F-gases emissions for the period 1990-2004 (in kt CO2 eq)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
HFC-23	0.99	1.17	0.96	1.70	2.27	3.45	3.97	4.20	4.63	5.34	3.99	3.41	3.44	2.89	2.78
HFC-32	NO	NO	NO	NO	NO	0.03	0.22	0.73	1.46	2.46	4.80	9.26	15.19	24.45	36.35
HFC-125	NO	NO	NO	NO	NO	5.52	10.97	21.83	35.74	52.04	81.91	124.35	179.38	254.03	345.33
HFC-134a	NO	NO	NO	0.09	0.15	24.85	47.66	86.64	136.16	195.47	278.08	388.28	497.63	615.97	750.16
HFC-143a	NO	NO	NO	NO	NO	9.57	17.65	32.44	50.70	70.75	102.13	136.99	180.72	230.57	286.01
HFC-152a	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	3.10	57.00	90.85	98.68
HFC-227ea	NO	NO	NO	NO	NO	NO	NO	NO	NO	3.29	4.58	6.27	8.15	10.50	13.81
R600a	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
R1234yf	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PFC-116	28.82	28.96	28.44	17.11	10.65	9.52	8.14	20.57	26.92	21.32	28.62	25.20	30.95	37.17	39.61
TOTAL HFCs	**991.01**	**1173.04**	**962.74**	**1702.86**	**2272.32**	**3487.68**	**4046.99**	**4344.36**	**4856.97**	**5667.03**	**4460.65**	**4079.50**	**4375.21**	**4112.54**	**4309.68**
TOTAL PFCs	**171.09**	**171.93**	**168.83**	**101.56**	**63.23**	**56.52**	**48.32**	**113.00**	**139.86**	**94.78**	**110.09**	**75.81**	**79.64**	**80.61**	**79.37**
TOTAL SF6	**3.02**	**3.11**	**3.21**	**3.30**	**3.39**	**3.53**	**3.62**	**3.67**	**3.71**	**3.81**	**3.92**	**4.00**	**4.18**	**4.18**	**4.39**
TOTAL	**1,162.10**	**1,344.97**	**1,131.57**	**1,804.42**	**2,335.55**	**3,544.20**	**4,095.31**	**4,457.36**	**4,996.84**	**5,761.81**	**4,570.73**	**4,155.31**	**4,454.85**	**4,193.16**	**4,389.05**

Table 2.6b Actual F-gases emissions for the period 2005-2019 (in kt CO2 eq)

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
HFC-23	2.37	0.10	0.14	0.16	0.16	0.19	0.16	0.18	0.19	0.15	0.15	0.13	0.12	0.10	0.09
HFC-32	48.92	63.61	79.93	95.69	110.73	133.50	164.62	207.56	280.16	305.90	310.70	345.28	332.06	338.35	310.98
HFC-125	479.19	578.89	728.37	856.94	969.30	1,162.25	1,354.22	1,622.64	1,984.60	2,141.87	2,298.14	2,575.87	2,662.76	2,661.16	2,496.68
HFC-134a	1,060.87	1,221.05	1,386.54	1,583.20	1,645.43	1,694.75	1,712.86	1,679.40	1,780.56	1,703.53	1,724.26	1,662.88	1,530.14	1,378.82	1,226.00
HFC-143a	405.59	439.28	536.98	603.46	641.97	744.67	776.47	848.63	851.90	878.39	832.00	798.39	820.81	740.89	675.31
HFC-152a	117.58	148.68	157.08	169.57	172.79	178.01	180.69	185.94	176.28	176.99	178.14	179.15	180.09	181.11	182.11
HFC-227ea	17.54	21.41	25.56	29.61	105.68	116.63	126.92	135.94	143.38	147.37	151.07	154.23	160.74	159.04	157.58
R600a	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00
R1234yf	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00
PFC-116	43.17	45.01	60.62	66.42	63.23	87.91	65.85	90.15	94.30	62.18	58.79	56.01	52.13	48.10	45.17
TOTAL HFCs	**4503.29**	**2568.97**	**3058.38**	**3494.70**	**3805.73**	**4215.53**	**4480.25**	**4864.48**	**5403.54**	**5505.32**	**5641.71**	**5844.57**	**5806.45**	**5559.42**	**5137.08**
TOTAL PFCs	**82.70**	**78.87**	**93.29**	**107.64**	**82.83**	**117.35**	**100.08**	**133.83**	**156.13**	**121.65**	**108.05**	**122.05**	**113.58**	**122.07**	**123.63**
TOTAL SF6	**6.35**	**8.23**	**9.75**	**7.40**	**5.17**	**6.04**	**5.29**	**5.20**	**5.31**	**5.07**	**5.22**	**5.36**	**5.16**	**5.09**	**5.07**
TOTAL	**4,585.99**	**2,647.84**	**3,151.67**	**3,602.35**	**3,888.56**	**4,332.88**	**4,580.33**	**4,998.31**	**5,559.67**	**5,626.97**	**5,749.76**	**5,966.62**	**5,920.03**	**5,681.49**	**5,260.71**

Table 2.6c Actual F-gases emissions for the period 2020-2023 (in kt CO2 eq)

Year	2020	2021	2022	2023
HFC-23	0.08	0.08	0.07	0.07
HFC-32	289.34	278.31	282.83	282.72
HFC-125	2,368.00	2,324.63	2,299.08	2,296.61
HFC-134a	1,104.45	1,061.45	1,040.35	1,029.00
HFC-143a	630.93	592.29	545.34	537.63
HFC-152a	183.06	183.00	164.29	121.83
HFC-227ea	159.20	159.32	152.84	153.21
R600a	0.00	0.00	0.00	0.00
R1234yf	0.00	0.00	0.00	0.00
PFC-116	44.90	39.81	34.93	34.16
TOTAL HFCs	**4816.27**	**4675.61**	**4558.17**	**4491.83**
TOTAL PFCs	**133.54**	**111.18**	**87.37**	**87.07**
TOTAL SF6	**5.09**	**5.03**	**5.03**	**5.05**
TOTAL	**4949.81**	**4786.78**	**4645.54**	**4578.90**

3. Energy (CRT sector 1)

3.1 Overview of sector

In this chapter, estimations for greenhouse gas emissions from the energy sector are presented and the methodological approach followed per source category is described.

According to the 2006 IPCC Guidelines, this sector includes two general source categories: fuel combustion activities and fugitive emissions from fuels.

In the present report and for presentation purposes, fuel combustion activities are further divided in two main categories, on the basis of the characteristics of the methodology applied for the calculation of emissions:

- Stationary combustion, including energy industries, manufacturing industries and construction and the other sectors (agriculture, residential and commercial / institutional sectors).
- Transport, including internal civil aviation, road transport, railways and internal navigation.

3.1.1 Emissions trends

The energy sector relies on fossil fuel combustion for meeting the bulk of energy requirements in Greece. As shown in ***Figure 3.1***, gross inland consumption in 2023 amounted to approximately 819.1 PJ. The consumption of solid fuels and oil products accounts for 59.4% of total consumption, while the contribution of biomass and of the rest renewable energy sources (mostly hydropower, solar, wind energy and geothermal) are 6.9% and 12.3% respectively. Finally, the share of natural gas in gross inland consumption is 19.2%, while the rest of gross inland consumption is covered by electricity (net imports – exports). In 2023, gross inland consumption (including liquid, solid, gaseous and biomass fuels) decreased by approximately 17.3% compared to 1990. It should be mentioned that up to 1996 supply of natural gas was exclusively minor quantities from domestic primary production. In essence, the introduction of natural gas in the Greek energy system started in 1997 and since then its consumption has been continuously increasing.

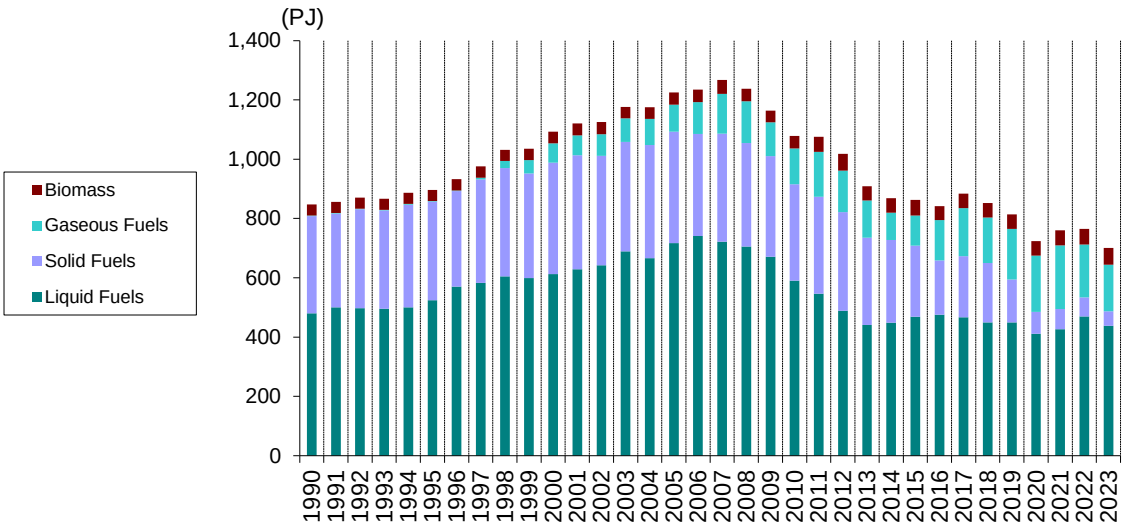


Figure 3.1 Gross inland consumption (in PJ) by energy type for the period 1990 – 2023

GHG emissions from *Energy* in 2023 decreased by 36.93% compared to 1990 (***Figure 3.2***). The highest increase on an annual basis (compared to the previous year) was recorded in 1997 (emissions increased by 5.5%), due to the significant increase in electricity demand as a result of particular weather conditions (very high summer temperatures), while the highest decrease on an annual basis was recorded in 2020 mainly due to the significant reduction of the operation of lignite-fired plants, which were replaced by higher share of NG and renewables compared to previous years, and the COVID-19 restrictions in transport sector. GHG emissions increased by 5.5% in 2022 compared to 2020, but decreased by 10.7% in 2023 compared to 2022.

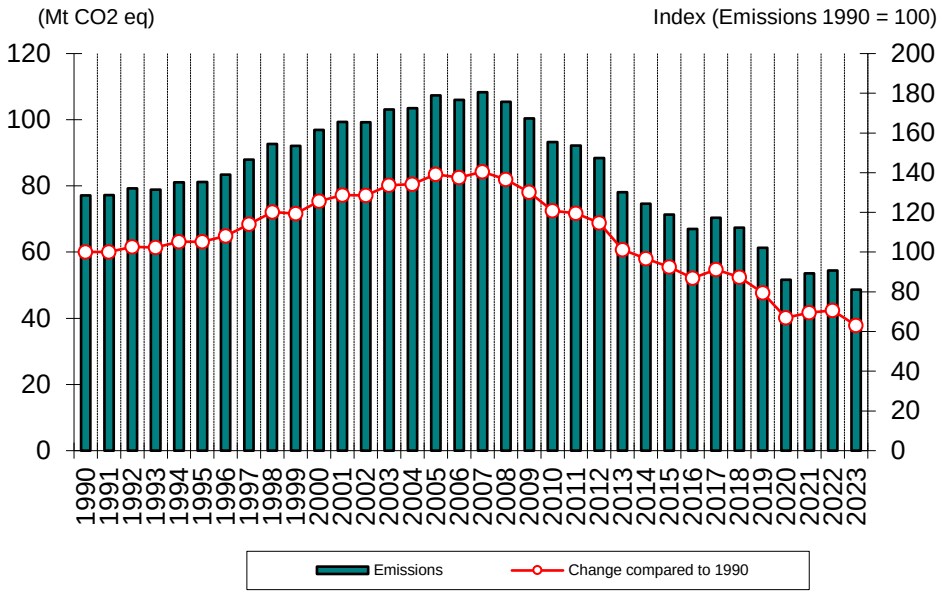


Figure 3.2 Total GHG emissions from Energy (in Mt CO2 eq) for the period 1990 – 2023

The evolution of GHG emissions from *Energy* can be distinguished into five periods that are related to economic development and the penetration of natural gas. At first (1990 – 1995) GHG

emissions increased with an average annual rate of 1.0% while Gross Domestic Product (GDP) increased with an annual rate of 1.7%. Then and up to 2000, GHG emissions increased with an annual rate of 3.6% which is higher than the rate of increase of GDP for the same period (3.4%). The average annual rate of emissions increase for the period 2000 – 2005 was 2.1% while GDP increased with higher rate (approximately 4%). For the period 2005-2008, a stabilization of the emission levels is observed, although the GDP increased with an annual rate of 3.3%. Finally, a reduction of emissions is observed by 41.9% in 2019 compared to 2008, due to the economic recession at the beginning of the period, but also due to measures as the increase of RES and NG share of the energy mixture, along with energy efficiency improvement actions. In addition, the high decrease in 2020 compared to 2019 is mainly attributed to the significant reduction of the operation of lignite-fired plants, which were replaced by higher share of NG and renewables compared to previous years, and the COVID-19 restrictions in transport sector. According to the NECP of Greece, there is an undergoing plan for the phasing-out of all but one lignite-plants by 2023. The remaining plant will be converted to NG by 2028. GHG emissions have increased by 5.5% in 2022 compared to 2020, which is attributed to the removal of COVID-19 confinement measures, but decreased by 10.7% in 2023 compared to 2022.

Energy is mainly responsible for carbon dioxide emissions, while it contributes also to methane and nitrous oxide emissions. Emissions from energy per greenhouse gas are presented in ***Table 3.1***.

The majority of GHG emissions (43.1%) in 2023 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 36.1%, 8.9% and 10.4% respectively. The rest 0.7% and 0.7% of total GHG emissions from *Energy* derived from fugitive emissions from fuels and other (mobile).

Within the fuel combustion activities, the only sector with increased emissions compared to 1990 is transport, showing an increase of 20.92%. It should be noted that GHG emissions from transport were reduced by 14% in 2020 compared to 2019 at a significant share due to COVID-19 restrictions, but in 2022 they have recovered their 2019 levels. Emissions from manufacturing industries and construction, energy industries and other sectors (i.e. residential, tertiary and agriculture sectors) had decreased by around 53.75%, 51.55% and 41.26%, respectively, compared to 1990. The decrease in the other sectors (i.e. residential, tertiary and agriculture sectors) is noticeable during the recent years, with the exception of 2020 compared to 2019, where the increase of emissions is attributed to a significant share of the COVID-19 restrictions in transport. Finally, fugitive emissions from fuels decreased by 71.10% for the period 1990 – 2023, due to the reduction of the use of lignite for power production.

Table 3.1 GHG emissions from Energy by source category and gas for the period 1990 – 2023

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO2 emissions (in Mt)																					
A. Fuel Combustion																					
Energy Industries	43.09	41.93	44.21	44.11	46.09	44.86	44.04	47.47	50.00	50.29	54.74	55.25	54.68	55.92	57.24	58.06	55.90	59.37	58.02	54.48	52.04
Industry	9.34	9.39	9.04	8.76	8.61	9.48	10.09	10.19	10.15	9.14	9.85	9.97	9.43	9.10	8.62	10.13	10.37	9.96	9.33	7.44	6.81
Transport	14.12	14.93	15.30	15.47	15.77	16.10	16.55	17.26	19.02	19.33	18.39	19.25	19.57	20.65	21.09	21.38	22.06	22.69	21.98	24.83	22.05
Other Sectors	8.07	8.45	8.08	7.94	8.00	8.08	10.00	10.26	10.61	10.44	11.05	11.90	12.44	14.36	13.56	14.21	14.10	12.73	12.45	10.67	9.57
Other	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	0.52	0.65	0.55	0.70	0.25	0.24
B. Fugitive Emissions from Fuels																					
Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Oil and Natural Gas	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01
CH4 emissions (in kt)																					
A. Fuel Combustion																					
Energy Industries	0.57	0.57	0.58	0.59	0.60	0.61	0.60	0.63	0.65	0.66	0.73	0.72	0.72	0.75	0.74	0.77	0.77	0.82	0.82	0.72	0.66
Industry	0.49	0.48	0.48	0.46	0.45	0.48	0.51	0.51	0.49	0.47	0.53	0.52	0.53	0.47	0.47	0.57	0.54	0.52	0.56	0.49	0.47
Transport	4.42	4.46	4.41	4.46	4.45	4.50	4.52	4.60	4.76	4.89	4.92	5.05	4.98	4.95	4.99	4.88	4.80	4.58	4.30	4.10	4.33
Other Sectors	9.54	9.67	9.64	9.63	9.62	9.59	9.64	9.68	9.60	9.47	9.52	9.50	9.39	9.40	9.41	9.42	9.39	10.08	8.29	7.37	7.62
Other	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	0.00	0.00	0.00	0.00	0.00	0.00
B. Fugitive Emissions from Fuels																					
Solid Fuels	45.20	45.90	47.95	47.75	49.36	50.22	52.07	51.25	53.03	54.05	55.65	57.79	61.38	59.49	61.01	60.45	56.20	57.89	57.24	56.52	49.23
Oil and Natural Gas	1.46	1.40	1.28	1.02	0.90	0.86	0.99	1.11	1.66	1.62	2.28	2.18	2.29	2.50	2.70	2.91	3.29	3.66	3.87	3.64	3.95
N2O emissions																					
A. Fuel Combustion (in kt)																					
Energy Industries	0.49	0.47	0.50	0.50	0.52	0.50	0.49	0.53	0.56	0.55	0.59	0.60	0.59	0.60	0.61	0.62	0.58	0.60	0.59	0.57	0.53
Industry	0.18	0.18	0.18	0.18	0.18	0.20	0.23	0.24	0.23	0.20	0.24	0.24	0.24	0.22	0.22	0.29	0.31	0.30	0.32	0.29	0.25
Transport	0.91	0.96	1.03	1.13	1.20	1.24	1.22	1.32	1.58	1.62	1.16	1.30	1.29	1.27	1.32	1.33	1.41	1.37	1.34	1.21	1.06
Other Sectors	1.17	1.22	1.14	1.13	1.12	1.05	1.08	1.08	1.08	1.08	1.08	1.10	1.20	1.30	1.13	1.15	1.19	1.08	1.03	0.83	0.75
Other	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	NO,IE	0.01	0.02	0.02	0.02	0.01	0.01
B. Fugitive Emissions from Fuels (in t)																					
Solid Fuels	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
Oil and Natural Gas	0.59	0.60	0.50	0.41	0.38	0.33	0.36	0.33	0.22	0.01	0.19	0.13	0.13	0.09	0.09	0.08	0.07	0.06	0.05	0.06	0.09

NA: Not Applicable, NO: Not Occurring

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO2 emissions (in Mt)													
A. Fuel Combustion													
Energy Industries	53.84	54.51	49.21	45.78	40.78	36.91	39.82	38.15	31.89	24.43	25.42	24.68	20.91
Industry	4.92	5.46	5.23	5.40	5.17	5.29	5.72	5.05	4.57	4.41	4.78	4.40	4.30
Transport	19.77	16.47	16.25	16.27	16.80	17.13	16.90	17.13	17.52	15.04	16.44	17.62	17.25
Other Sectors	10.80	9.26	4.90	4.81	6.26	5.81	5.86	5.12	5.65	6.28	5.73	6.22	4.74
Other	0.22	0.21	0.24	0.19	0.21	0.20	0.18	0.12	0.13	0.30	0.04	0.30	0.35
B. Fugitive Emissions from Fuels													
Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Oil and Natural Gas	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
CH4 emissions (in kt)													
A. Fuel Combustion													
Energy Industries	0.67	0.67	0.63	0.59	0.55	0.54	0.58	0.55	0.51	0.43	0.45	0.45	0.40
Industry	0.45	0.37	0.26	0.31	0.35	0.29	0.32	0.36	0.37	0.40	0.41	0.41	0.42
Transport	3.77	2.85	3.21	3.05	2.95	2.80	2.72	2.72	2.67	2.20	2.43	2.49	2.34
Other Sectors	10.02	12.50	10.28	9.90	10.40	9.06	9.28	8.77	8.53	8.03	8.61	9.02	9.44
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B. Fugitive Emissions from Fuels													
Solid Fuels	51.10	54.83	46.97	44.29	40.28	28.43	32.86	31.78	23.84	12.24	10.80	12.41	9.38
Oil and Natural Gas	4.70	4.41	4.04	3.53	3.81	4.26	5.11	4.82	4.98	5.22	5.68	4.63	4.43
N2O emissions													
A. Fuel Combustion (in kt)													
Energy Industries	0.54	0.55	0.49	0.46	0.41	0.33	0.37	0.35	0.27	0.16	0.15	0.15	0.12
Industry	0.19	0.20	0.17	0.23	0.25	0.21	0.21	0.23	0.14	0.13	0.13	0.25	0.14
Transport	0.82	0.67	0.63	0.67	0.72	0.78	0.79	0.81	0.81	0.65	0.74	0.82	0.82
Other Sectors	0.83	0.28	0.27	0.29	0.31	0.26	0.26	0.26	0.25	0.33	0.29	0.29	0.27
Other	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01
B. Fugitive Emissions from Fuels (in t)													
Solid Fuels	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO	NA,NO
Oil and Natural Gas	0.07	0.07	0.05	0.05	0.05	0.13	0.11	0.16	0.13	0.07	0.05	0.02	0.04

3.1.2 Methodology

The calculation of GHG emissions from fuel combustion activities is based on the 2006 IPCC Guidelines.

The methodology applied for the calculation of emissions by source category for years 1990-2023 is briefly presented in ***Table 3.2***.

Table 3.2 Methodology for the estimation of emissions from energy

CRT	IPCC categories	CO_2		CH_4		N_2O	
1A	Fuel combustion	Method	Emission factor	Method	Emission factor	Method	Emission factor
1A1	Energy industries						
1A1a	Public electricity and heat production	T2	CS, PS	T1	D	T1	D
1A1b	Petroleum refining	T2	PS	T1	D	T1	D
1A1c	Solid fuel manufacturing and other energy industries	T2	PS	T1	D	T1	D
1A2	Manufacturing industries and Construction	T2	CS, PS	T1	D	T1	D
1A3	Transport						
1A3a	Aviation	T2/T3	D	T2/T3	D	T2/T3	D
1A3b	Road transport	T2	CS	M	M, D	M	M, D
1A3c	Railways	T2	CS	T1	CR	T1	CR
1A3d	Navigation	T2	CS	T1	CR	T1	CR
1A3e	Pipeline transport	T2	CS	T1	D	T1	D
1A4	Other sectors						
1A4a	Commercial / Institutional	T2	CS, D	T1	D	T1	D
1A4b	Residential	T2	CS, D	T1	D	T1	D
1A4c	Agriculture / Forestry / Fisheries	T2	CS, D	T1	D	T1	D
1B	Fugitive emissions from fuels						
1B1	Solid fuels	NA	NA	T1	D	NA	NA
1B2	Oil and Natural gas	T1	D	T1	D	T1	D
	International transport						
	Aviation	T2/T3	D	T2/T3	D	T2/T3	D
	Marine	T2	CS	T1	CR	T1	CR

CR=Corinair. CS= Country specific emission factor. PS= Plant Specific. T2a = IPCC Tier 2a. T1= IPCC Tier 1. D = IPCC Default. M= Copert IV model

The energy data used for the calculation of emissions derived from the national energy balance and the reports of installations under the EU ETS. The Ministry of Transport and the Hellenic Statistical Authority are the main sources of information regarding road transport, while data on civil aviation come from the Civil Aviation Organization and Euro control.

Key categories

The key categories identified in the energy sector are presented in ***Table 3.3*** (see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations). These sources are responsible for about 70% of total national GHG emissions in 2023 (without *LULUCF*).

Table 3.3 Key categories from Energy

IPCC source categories	Gas	Criteria
Energy industries – Liquid fuels	CO_2	Level, Trend
Energy industries– Solid fuels	CO_2	Level, Trend
Energy industries – Gaseous fuels	CO_2	Level, Trend
Manufacturing Industries & Construction – Solid fuels	CO_2	Trend
Manufacturing Industries & Construction – Liquid fuels	CO_2	Level, Trend
Manufacturing Industries & Construction – Gaseous fuels	CO_2	Level, Trend
Transport – Road transport	CO_2	Level, Trend
Transport – Navigation	CO_2	Level, Trend
Transport – Civil Aviation	CO_2	Level
Coal mining and handling	CH_4	Trend
Other Sectors – Liquid fuels	CO_2	Level, Trend
Other Sectors – Gaseous fuels	CO_2	Level, Trend

Uncertainty

The results of the uncertainty analysis undertaken for the Greek GHG emissions inventory are presented in Paragraph 1.7, while the detailed calculations are presented in Annex IV. In general, the uncertainty of emissions estimates for the energy sector is relatively small (***Table 1.9***). In ***Table IV.1 and IV.2*** the uncertainty of activity data and emission factors is illustrated.

3.1.3 Completeness

Table 3.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in the energy sector.

Table 3.4 Energy – Completeness of emissions inventory

ENERGY	Greenhouse gases						Other gases			
	CO_2	CH_4	N_2O	HFC	PFC	SF_6	Nox	CO	NMVOC	SO_2
Energy industries										
Public electricity and heat production	☒	☒	☒				☒	☒	☒	☒
Petroleum refining	☒	☒	☒				☒	☒	☒	☒
Manufacturing of solid fuels and other energy industries	☒	☒	☒				☒	☒	☒	
Manufacturing industries and Construction										
Iron and steel	☒	☒	☒				☒	☒	☒	☒
Non ferrous metals	☒	☒	☒				☒	☒	☒	☒
Chemicals	☒	☒	☒				☒	☒	☒	☒
Paper. Pulp and print	☒	☒	☒				☒	☒	☒	☒
Food processing. Beverages and Tobacco	☒	☒	☒				☒	☒	☒	☒
Other industries	☒	☒	☒				☒	☒	☒	☒
Transport										
Aviation	☒	☒	☒				☒	☒	☒	☒
Road transport	☒	☒	☒				☒	☒	☒	☒
Railways	☒	☒	☒				☒	☒	☒	☒
Navigation	☒	☒	☒				☒	☒	☒	☒
Pipeline transport	☒	☒	☒				☒	☒	☒	☒
Other sectors										
Commercial / Institutional	☒	☒	☒				☒	☒	☒	☒
Residential	☒	☒	☒				☒	☒	☒	☒
Agriculture / Forestry / Fisheries	☒	☒	☒				☒	☒	☒	☒
Fugitive emissions from fuels										
Solid fuels	IE/NO	☒	NA/NO				NA	NA	NA	
Oil	☒	☒	☒				☒	☒	☒	☒
Natural gas	☒	☒	☒						NE	NE
International transport [1)]										
Aviation	☒	☒	☒				☒	☒	☒	☒
Marine	☒	☒	☒				☒	☒	☒	☒

Emissions from international transport are not included in national totals

IE: Include Elsewhere

NE: Not Estimated

NA: Not Applicable

3.2 Fuel Combustion (CRT Source Category 1.A)

3.2.1 Comparison of the sectoral approach with the reference approach

According to the 2006 IPCC Guidelines and UNFCCC reporting GLs, carbon dioxide emissions from the energy sector should be calculated using both the reference and the sectoral approach (see Sections 3.2 – 3.3). The reference approach (see **Annex III** for an analytical presentation of the methodology) is based on detailed data on primary energy consumption, which lead to the calculation of apparent consumption and to the consequent calculation of CO_2 emissions, while the sectoral approach is based on a detailed disaggregation of energy consumption by sector, fuel and technology for the calculation of CO_2 emissions.

The application of the reference approach can be considered as a quality control procedure, as the deviation of estimations should not be significant (deviations in the order of ±2%) or else explanations should be provided. The estimation of carbon dioxide emissions according to the two methodologies is presented in ***Table 3.5***.

Table 3.5 ***CO_2 emissions (in kt) according to the reference and the sectoral approach for the period 1990 – 2023***

Year	Reference approach	Sectoral approach	Deviation %
1990	74,770	74,622	0.20
1991	75,322	74,695	0.84
1992	77,859	76,643	1.59
1993	77,056	76,288	1.01
1994	79,790	78,463	1.69
1995	79,288	78,517	0.98
1996	80,047	80,673	-0.78
1997	84,059	85,188	-1.33
1998	88,361	89,780	-1.58
1999	87,813	89,207	-1.56
2000	92,316	94,026	-1.82
2001	95,257	96,383	-1.17
2002	95,188	96,123	-0.97
2003	96,818	100,031	-3.21
2004	98,484	100,503	-2.01
2005	100,460	104,304	-3.69
2006	97,274	103,076	-5.63
2007	98,475	105,293	-6.48
2008	97,684	102,478	-4.68
2009	94,523	97,673	-3.22
2010	87,705	90,720	-3.32
2011	85,888	89,554	-4.09
2012	86,381	85,898	0.56

Year	Reference approach	Sectoral approach	Deviation %
2013	73,790	75,819	-2.68
2014	71,695	72,452	-1.04
2015	68,368	69,217	-1.23
2016	64,067	65,346	-1.96
2017	66,941	68,483	-2.25
2018	63,750	65,571	-2.78
2019	58,435	59,748	-2.20
2020	49,192	50,153	-2.62
2021	50,664	52,445	-3.39
2022	53,225	51,039	-4.11
2023	46,089	47,547	-3.06

As shown in the table above, the estimated deviation (which ranges from –6.48% to 1.69%), while the deviation of most years is within the threshold defined by the 2006 IPCC Guidelines. The existing differences result mainly from:

1. ***Statistical differences in fuel consumption***. The sectoral approach uses the actual consumption of the different fuels, while the reference approach uses their apparent consumption. Theoretically, both consumption estimates should be equal, but there is usually a difference between them (statistical differences) due to the collection of information from different sources. The reference approach does not provide for the calculation of these differences. The deviation in the calculation of the consumption of liquid fuels (***Table 3.6***) is mainly attributed to the statistical differences.
2. ***Losses from transformation, transport and distribution***. During the refining of crude oil and the transmission/distribution of natural gas losses may occur, due to possible leaks in the refining systems, the transmission/distribution pipelines etc. These losses are not taken into account in the reference approach.
3. ***Emission factors***. In the reference approach, CO_2 emissions from liquid fuel consumption are mainly estimated assuming "combustion" of crude oil. On the contrary, the sectoral approach calculates emissions using the actual consumption per liquid fuel and appropriate emission factors. Additionally, the emission factor as well as the calorific value of solid fuels (lignite) is differentiated by sector, resulting in deviations in the calculated energy consumption.

The amount "Apparent energy consumption (excluding non-energy use and feedstocks)" of the CRT Table 1A(c) was calculated from the apparent energy consumption calculated through the reference approach excluding the fuel amounts that were not included in the sectoral approach. Therefore, it was calculated by subtracting the following fuel consumption per fuel:

- Liquid fuels: bitumen, which was consumed in the construction industry, and petcoke, which was consumed in the non-ferrous industry (the associated emissions were included in the IPPU sector).

- Solid fuels: coal and lignite, which were consumed in the non-ferrous industry (the associated emissions were included in the IPPU sector).
- Gaseous fuels: natural gas, which was used as feedstock for the production of ammonia and hydrogen (the associated emissions were included in the IPPU sector).

Table 3.6 ***Deviations during the calculation of energy consumption (apparent and actual) for the period 1990 – 2023 (%)***

Year	Liquid fuels	Solid fuels	Gaseous fuels
1990	2.97	0.44	0.00
1991	4.10	0.60	-0.63
1992	5.93	1.40	-0.84
1993	3.24	1.48	-0.88
1994	5.17	1.43	-0.09
1995	1.05	4.09	0.00
1996	0.40	1.60	0.00
1997	-0.65	1.14	1.05
1998	-1.23	1.18	0.15
1999	-0.81	0.76	-0.06
2000	-0.49	-0.29	0.80
2001	0.38	0.13	1.42
2002	0.77	0.39	0.03
2003	-2.81	-0.60	0.09
2004	0.34	-1.38	-0.20
2005	-3.36	-0.55	2.03
2006	-7.43	-0.03	2.05
2007	-10.36	0.37	0.40
2008	-5.72	-1.58	-1.73
2009	-4.24	0.57	1.95
2010	-5.50	0.96	2.23
2011	-7.57	0.12	2.61
2012	3.21	-0.03	2.77
2013	-2.98	0.07	0.74
2014	-1.12	-0.05	0.62
2015	-1.11	0.02	1.30
2016	-1.26	0.24	1.49
2017	-2.55	0.43	-0.06
2018	-3.61	0.07	1.33
2019	-1.99	-0.25	1.15
2020	-2.32	1.10	0.58
2021	-3.03	0.68	0.50
2022	-4.11	1.61	0.68
2023	-3.84	1.25	0.70

3.2.2 International bunker fuels

GHG emissions from international aviation and marine bunkers are calculated with the same methodologies as described for internal aviation and navigation. The fuel consumption data used are taken from the national energy balance, as declared by oil trading companies. Finally, the allocation of LTOs between domestic and international aviation was based, up to 2005, on data provided by the Civil Aviation Organisation (***Table 3.7***). From 2005 and on, the corresponding EUROCONTROL calculation data were used, as they were considered more reliable than CAO's data. In order to keep timeseries consistency, it was decided to recalculate emissions from 1990-2005 taking into account only international aviation fuel consumption and by applying Tier 1 methodology.

For marine bunkers, after a research made with the Laboratory of Fuels of the National Technical University of Athens, country specific carbon content was applied (as it was already done for the whole timeseries).

GHG emissions from international bunkers ***(Table 3.8 a,b,c)*** decreased by 19% since 1990 for marine bunkers and increased by 68% for international aviation. The significant reductions occurred in 2020 and continued to appear in 2021, due to the preventive measures which were being implemented in Greece, to limit the spread of the coronavirus disease in the country. However, in 2023, they recovered to their 2019 levels.

Table 3.7 Allocation of LTOs to domestic and international aviation for the period 1990-2023

Year	Domestic	International
1990	60535	61803
1991	52653	59037
1992	57949	71603
1993	63750	74699
1994	63783	80487
1995	67626	78556,5
1996	72558	76995
1997	82440	83806
1998	83851	87857
1999	100264	98049
2000	111481	102174
2001	99765	98332
2002	85721	94421
2003	97974	99913
2004	106108	103818
2005	100336	101246

Year	Domestic	International
2006	105927	108783
2007	111424	116176
2008	107182	113275
2009	120063	108790
2010	108102	106330
2011	94687	110427
2012	95044	104735
2013	87392	107841
2013	87392	107841
2014	91453	123532
2015	98846	129693
2016	102039	139223
2017	102479	149254
2018	110021	166953
2019	113010	168291
2020	67404	65600
2021	92714	116608
2022	111430	171477
2023	107613	168961

Table 3.8(a) GHG emissions in the transportation sector per category. For the period 1990 – 2000

Memo items 1) – International bunkers											
Emissions (kt CO_2 eq)											
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
International aviation	2493.90	2150.17	2242.82	2388.80	2834.17	2656.34	2544.87	2462.05	2583.09	2901.06	2544.87
International marine	8334.91	7659.64	8813.69	10271.96	10920.94	11764.38	10331.72	10358.72	11536.14	10255.43	11825.81

1) Emissions from international transport are not included in national emissions

Table 3.8(b) GHG emissions in the transportation sector per category. For the period 2001 – 2011

Memo items 1) – International bunkers											
Emissions (kt CO_2 eq)											
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
International aviation	2366.42	2366.50	3079.92	3165.35	2620.29	2800.59	2970.77	2953.22	2738.61	2603.83	2716.57
International marine	11454.70	10253.07	10493.79	10571.58	9415.99	10160.51	10359.74	10125.84	8604.08	8974.22	9131.45

1) Emissions from international transport are not included in national emissions

Table 3.8(c) GHG emissions in the transportation sector per category. For 2012-2023

	Memo items 1) – International bunkers											
	Emissions (kt CO_2 eq)											
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
International aviation	2405.16	2485.23	2851.48	2890.94	3103.56	3461.08	3887.96	4019.28	1333.62	2530.77	3971.77	4197.33
International marine	7489.70	7066.98	6184.14	5934.00	5730.79	7119.88	7287.03	8414.13	5490.62	6095.55	6582.57	6750.19

1) Emissions from international transport are not included in national emissions

3.2.3 Feedstocks and non-energy use of fuels

Non-energy fuel use concerns the consumption of fuels as raw materials (e.g. in chemical industry, metal production) for the production of other products, or the use of fuels for non-energy purposes (e.g. bitumen). Part of the carbon content of fuels is stored in final products and is not oxidized into carbon dioxide for a certain time period. The fraction of the carbon contained in final products and the time period for which carbon is stored in them, depend on the type of fuel used and of the products produced.

The oxidation of the carbon stored in final products occurs either during the use of the product (e.g. solvents) or during their decomposition (e.g. through combustion). It should be noted that emissions during production processes (e.g. ammonia and hydrogen production) should be reported under the sector of IPPU, while emissions from burning of products should be reported under the waste sector or energy sector (as long as energy exploitation takes place).

Non-energy use of fuels in Greece refers to the consumption of:

- naphtha, natural gas, and lignite (for the period 1990 – 1991) in chemical industry,
- petroleum coke and solid fuels that are used as reduction agents in the iron, steel and non-ferrous metals industry are reported under the IPPU sector,
- lubricants in transport (including off-road transportation),
- bitumen in construction and
- other petroleum products in the industrial and residential sectors.

The calculation of carbon dioxide emissions from non-energy use of fuels is based on the relevant consumption by fuel type (***Table 3.9***) and the fraction of the carbon stored by fuel type (or the carbon excluded form reference approach) (***Table 3.10***), according to the following equation:

$$E = \sum_f FC_f \cdot CC_f \cdot (1 - CS_f)$$

where, E represents carbon emissions, f is the index of fuel type, FC_f is non-energy consumption of fuel f, CC_f is the carbon content of fuel f and CS_f is the fraction of carbon stored from the non-energy use of fuel f (or the carbon excluded form reference approach).

Data on the non-energy consumption of fuels derive mainly from the national energy balance. Moreover, plant specific data derived from verified ETS reports and information provided by specific Greek industries resulted to the improvement of reallocation of non-energy use fuels from the energy to the IPPU sector:

- The allocation between energy and non-energy use of natural gas for the category 1.A.2.c is based on verified ETS reports.

- The non-energy use of natural gas for ammonia production has been reallocated to IPPU sector since the 2012 inventory submission, by using data from ETS reports and plant specific information. Non-energy use of lignite is accounted in the IPPU sector and refers only to ammonia production (in one installation for 1990 and 1991) and as a result the fraction of carbon stored is equal to 0. The operation of this installation ended at 1998 while it did not produce ammonia for the period 1992 – 1998.
- The associated emissions of a small amount of liquid fuels, which was used as feedstock in ammonia production by one plant for the years 1990–1993 and 1995–1998, are included under the energy sector's inventory instead of the IPPU sector. This amount of liquid fuels is reported by aggregation in the energy balance; and thus it is difficult to obtain the historical data, given also the closure of the relevant plant. More information is provided in section 4.6.
- The non-energy use of natural gas for hydrogen production is included in the IPPU sector, by using data from EU ETS reports and information from Public Gas Corporation. The associated CO2 emissions from hydrogen production from liquid fuels are reported under the subcategory 1.A.1.b, because while disaggregated data on the amount of liquid fuels used for hydrogen production are available from the EU ETS reports for the period 2005–2023, for the period 1990–2004 the amount of liquid fuel used for hydrogen production is reported together with the amount of fuel combusted in the refineries as provided in the national energy balance. It is therefore not possible to report these emissions separately for the period 1990–2004.
- CO_2 emissions from the use of fuels as reduction agents in the iron and steel industry are reported under the IPPU sector.
- Solid fuels consumption in the ferroalloys production industry is included (in the national energy balance) in the solid fuels consumption of the non-ferrous metals sector. However, by using data from ETS reports and plant specific information, emissions from solid fuels for ferroalloys production are reallocated to the IPPU sector, as from 2010 submission.
- The non-energy use of petroleum coke (see Table 3.9) refers exclusively to the primary aluminium production. Given that the relevant emissions are reported under the IPPU sector, petroleum coke consumption is not taken into account in the energy sector.

On the basis of the above-mentioned clarifications, the possibility to double-count or underestimate CO_2 emissions from the non-energy use of fuels is minor.

Table 3.9 Non-energy fuel use (in PJ) for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Naphtha	2.7	3.2	2.3	2.3	1.5	3.2	3.9	2.2	0.6	1.0	2.1	1.7	0.9	2.7	4.6	3.7	6.0	6.6	4.1	4.3	5.0
Lubricants	5.3	3.5	3.5	3.4	3.5	3.0	2.7	3.2	2.1	2.6	2.3	3.2	2.2	2.6	2.8	3.2	4.9	4.1	2.8	1.8	1.6
Bitumen	8.2	9.0	9.4	10.0	10.2	12.0	12.2	12.3	13.9	14.2	16.3	16.6	17.3	14.8	16.6	11.1	14.5	12.2	18.8	15.0	10.8
Natural gas	4.0	3.9	3.7	2.4	NO	NO	NO	1.5	6.4	6.3	5.0	2.5	3.0	5.2	5.5	5.4	5.7	5.7	7.9	8.2	11.3
Lignite (ammonia)	3.2	3.1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Coal	2.3	2.4	2.3	1.8	3.0	2.8	3.2	2.4	2.1	1.7	1.9	3.8	4.4	4.4	3.8	3.4	2.4	3.5	3.5	2.9	4.6
Lignite	2.6	2.7	1.9	2.9	2.1	2.2	2.5	2.3	2.0	1.3	2.0	0.9	0.8	1.0	1.0	1.2	1.8	1.7	1.6	0.1	0.1
Petcoke	1.9	2.2	2.3	1.8	1.7	1.5	1.6	1.6	1.6	1.9	1.9	92.0	3.7	2.0	2.0	2.0	2.0	2.2	1.6	1.4	2.2

Other	2.4	0.4	1.2	0.5	1.2	1.0	0.8	0.9	1.2	0.4	2.9	3.7	4.7	7.5	5.8	6.8	5.5	4.6	4.4	5.5	12.4

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Naphtha	1.7	2.9	0.7	0.2	0.2	0.2	NO	1.1	1.2	1.0	1.3	0.5	NO
Lubricants	1.5	1.4	1.5	1.9	2.0	1.9	2.1	2.3	3.3	2.7	2.4	2.9	3.4
Bitumen	4.6	4.0	5.1	6.6	7.1	8.9	7.0	4.5	6,1	7.0	5.9	6.5	7.4
Natural gas	10.5	9.0	9.3	10.7	9.3	8.3	14.4	17.0	15.7	15.2	12.2	5.6	8.1
Lignite (ammonia)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Coal	5.6	6.3	5.2	4.7	5.0	6.5	6.9	6.3	5.3	2.8	1,8	NO	NO
Lignite	0.3	NO	0.4	1.1	1.0	0.1	0.1	0.1	0.0	NO	NO	NO	NO
Petcoke	1.6	0.4	1.1	1.0	0.4	1.3	0.1	0.1	0.0	NO	NO	NO	NO
Other	11.6	6.9	7.4	8.4	7.7	9.0	10.0	9.5	10.1	8.0	8.5	7.9	8.5

Table 3.10 Carbon excluded form reference approach

	Naphtha	Lubricants	Bitumen	Natural gas	Lignite	Petroleum coke	Paraffin waxes	Other oil products
Carbon stored	100%	100%	100%	100%	100%	100	100%	100%

NA: Not Applicable

The carbon excluded from the reference approach is 100% because either all carbon is stored in the final product (as in the case of bitumen), or the associated emissions were reported under IPPU sector.

The fuel consumption from non-energy fuel use per liquid, solid and gaseous fuels are presented in ***Table 3.11***.

Table 3.11 Fuel consumption from non-energy fuel use per liquid, solid and gaseous fuels for the period 1990 – 2023

Year	Liquid fuels (TJ)	Solid fuels (TJ)	Gaseous fuels (TJ)
1990	20,388	8,499	4,046
1991	18,220	6,727	3,866
1992	18,727	4,233	3,677
1993	18,046	4,696	2,370
1994	17,968	5,105	NO
1995	20,685	5,005	NO
1996	21,230	5,670	NO
1997	20,240	4,649	1,509
1998	19,385	4,107	6,370
1999	20,051	3,004	6,256
2000	25,466	3,919	5,006
2001	27,207	4,736	2,452
2002	28,842	5,148	2,992

Year	Liquid fuels (TJ)	Solid fuels (TJ)	Gaseous fuels (TJ)
2003	29,554	5,328	5,175
2004	31,850	4,765	5,496
2005	26,821	4,521	5,363
2006	32,951	4,150	5,670
2007	29,764	5,138	5,741
2008	31,670	5,090	7,941
2009	28,076	3,009	8,164
2010	32,012	4,695	11,330
2011	21,000	5,921	10,474
2012	15,691	6,332	8,983
2013	15,874	5,606	9,296
2014	18,070	5,785	10,705
2015	17,429	5,999	9,344
2016	21,233	6,598	8,263
2017	19,209	7,043	14,386
2018	17,435	6.403	17,024
2019	20,719	5,361	15,724
2020	18,732	2,759	15,155
2021	18,117	1,863	12,220
2022	17.843	NO	5,586
2023	19,275	NO	8,066

3.2.4 Stationary combustion (CRT Source Category 1.A except 1.A.3)

3.2.4.1 Source category description

As it was already mentioned, stationary combustion includes energy industries, manufacturing industries and construction and the other sectors (agriculture, residential and commercial/ institutional sectors).

The consumption of fossil fuels in these sectors accounts for 70% - 77% of total fossil fuel consumption in Greece for the period 1990 – 2023 (***Figure 3.3***).

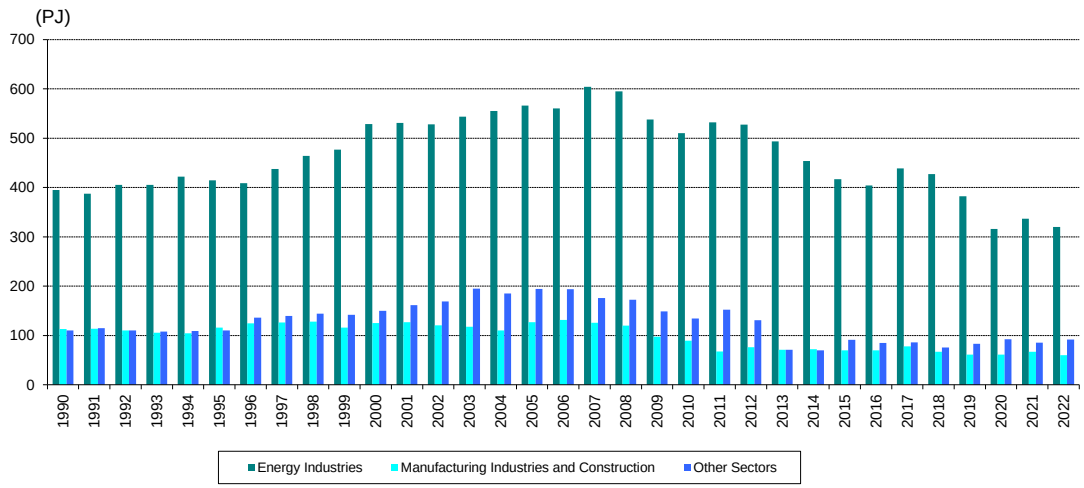


Figure 3.3 Consumption of fossil fuels (in PJ) in stationary combustion for the period 1990 – 2023

The consumption of fossil fuels in 2023 decreased by approximately 33.9% compared to 1990.

- Fuel consumption in energy industries accounts for 67.5% (average value for the period 1990 – 2023) of fuel consumption in stationary combustion. It has been decreased by 29.6% in 2023 compared to 1990 levels. It is noted, however, that an increase took place mostly after 1996, due to the significant increase of electricity consumption attributed to the improvement of living standards. During the years 2008 – 2023 the fuel consumption in energy industries had a decreasing trend with an average annual rate of 4.5% (with the exception of year 2011, 2017 and 2021). In 2019, it decreased by 10.5% compared to 2018, and in 2020 by 17.3% compared to 2019, due to the gradual phasing-out of lignite-fired power plants and increase in use of RES and NG for power generation. In 2021, it increased by 6.4% compared to 2020, but then decreased again by 4.9 in 2022 compared to 2021. In 2022 it further decreased by 13.1% compared to 2021.

- The consumption of fossil fuels in industry presented significant variations on an annual basis that are related to the trend of the industrial production in Greece. Overall, fuel consumption in 2023 decreased by 47.3% compared to 1990 levels.
- Fossil fuels consumption in Other sectors decreased by 26.5% from 1990 to 2023.

GHG emissions from stationary combustion in general follow the trend of fossil fuels consumption. Therefore, GHG emissions in 2023 (30.72 Mt CO_2 eq) decreased by 49.9% compared to 1990 (61.28 Mt CO_2 eq) (***Figure 3.4***). The years 2008-2016, a decreasing trend of emissions is observed with average annual rate of 5.7%. This decreasing trend is attributed to the penetration of natural gas and RES technologies to the energy mix, the increased use of biomass during the recent years (residential sector), but also, to the economic recession that the country is facing. In 2017, GHG emissions were increased by 7.0% compared to 2016, which is attributed to a 12.2% increase of solid fuels use in category 1A1 in 2017 compared to 2016. The emissions in 2018 were decreased by 6.0% compared to 2017, and 12.9% in 2019 compared to 2018 which is mainly driven by a decrease of the use of solid fuels use in category 1A1 and replaced by RES. The gradual phasing-out of lignite-fired power plants affects the GHG emissions in 2020 and 2023, too, which decreased further by 16.0% and 14.8, respectively, compared to previous years.

It is noted that emissions from stationary combustion account for around 60% of total national emissions (without *LULUCF*) for the period 1990 – 2023, while **eight key categories** are included in this sector (**CO_2 emissions from solid, liquid and gaseous fuels combustion of Energy industries and Manufacturing industries; and CO_2 emissions from liquid and gaseous fuels combustion from Other sectors**.

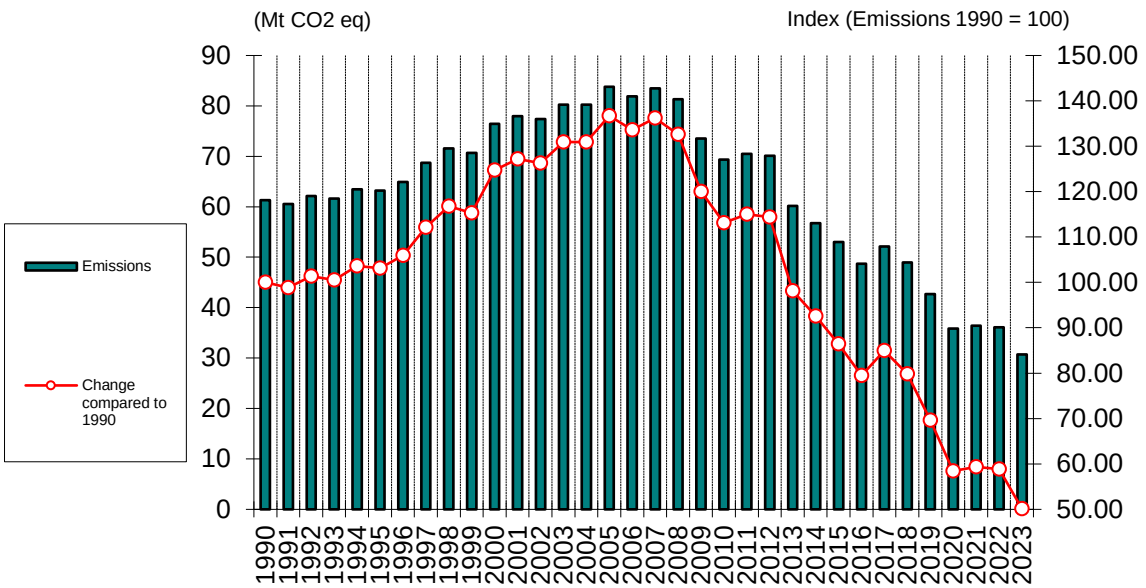


Figure 3.4 ***GHG emissions (in Mt CO_2 eq) from stationary combustion for the period 1990 – 2023***

Emissions from stationary combustion per gas and source category are presented in ***Table 3.12***.

Carbon dioxide represents the major GHG from stationary combustion with a share in total emissions from stationary combustion being 98.7% in 2023. Overall, CO_2 emissions in 2023 decreased by 50.5% compared to 1990 levels. N_2O emissions in 2023 account for 0.5% of emissions from stationary combustion, decreased by 71.2% compared to 1990. CH_4 emissions account for the rest 0.8% of total emissions of the sector and decreased by 3.2% from 1990 to 2023.

Table 3.12 GHG emissions per gas and source category from stationary combustion for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GHG emissions per gas																													
CO_2 (in Mt)	60.50	59.77	61.34	60.82	62.70	62.42	64.12	67.93	70.76	69.87	75.64	77.13	76.55	79.38	79.42	82.41	80.37	82.06	79.80	72.59	68.42	69.56	69.22	59.34	55.99	52.21	48.01	51.40	48.32
CH_4 (in kt)	10.59	10.72	10.70	10.68	10.68	10.67	10.75	10.82	10.74	10.61	10.79	10.74	10.64	10.61	10.63	10.76	10.70	11.42	9.67	8.58	8.75	11.15	13.53	11.17	10.79	11.30	9.89	10.18	9.69
N_2O (in kt)	1.84	1.87	1.82	1.80	1.82	1.76	1.80	1.85	1.86	1.83	1.91	1.93	2.02	2.12	1.96	2.06	2.07	1.98	1.94	1.69	1.53	1.56	1.03	0.94	0.98	0.96	0.80	0.84	0.84
GHG emissions per source category (in Mt CO_2 eq)																													
Energy industries	43.25	42.09	44.38	44.27	46.26	45.02	44.20	47.65	50.18	50.47	54.93	55.45	54.87	56.12	57.44	58.26	56.09	59.57	58.21	54.67	52.21	54.02	54.69	49.37	45.94	40.91	37.02	39.94	38.27
Man. Industry and cons	9.40	9.45	9.11	8.82	8.67	9.55	10.17	10.28	10.23	9.21	9.93	10.06	9.51	9.18	8.70	10.24	10.47	10.06	9.43	7.54	6.90	4.98	5.53	5.29	5.47	5.25	5.36	5.79	5.13
Other sectors	8.65	9.05	8.67	8.52	8.57	8.63	10.56	10.83	11.18	11.00	11.61	12.47	13.04	14.98	14.13	14.79	14.69	13.30	12.97	11.11	9.99	11.30	9.65	5.24	5.14	6.61	6.12	6.17	5.42
TOTAL (Mt CO_2 eq)	**61.31**	**60.60**	**62.15**	**61.62**	**63.51**	**63.21**	**64.93**	**68.75**	**71.58**	**70.68**	**76.47**	**77.98**	**77.42**	**80.28**	**80.27**	**83.29**	**81.26**	**82.94**	**80.62**	**73.31**	**69.10**	**70.30**	**69.87**	**59.90**	**56.55**	**52.78**	**48.50**	**51.90**	**48.81**

Year	2019	2020	2021	2022	2023
GHG emissions per gas					
CO_2 (in Mt)	42.10	35.12	35.93	35.30	29.95
CH_4 (in kt)	9.41	8.85	9.47	9.88	10.26
N_2O (in kt)	0.66	0.62	0.57	0.70	0.53
GHG emissions per source category (in Mt CO_2 eq)					
Energy industries	31.98	24.49	25.48	24.74	20.95
Man. Industry and cons	4.62	4.45	4.83	4.48	4.35
Other sectors	5.93	6.58	6.03	6.54	5.06
TOTAL (Mt CO_2 eq)	**42.53**	**35.52**	**36.34**	**35.76**	**30.36**

Energy industries constitute the major contributor (69% in 2023) in the overall GHG emissions from stationary combustion, followed by other sectors and manufacturing industry and construction. Emissions from other sectors decreased by 41.6% in 2023 compared to 1990, due to economic recession (the years after 2007), switch to biomass and natural gas, and energy efficiency measures. An increase of other sectors; GHG emissions by about 11% in 2020 compared to 2019 is attributed to a significant share of the COVID-19 restrictions resulting in an increase of residential energy use.

3.2.4.2 Methodological issues

The calculation of GHG emissions from stationary combustion was based on the 2006 IPCC Guidelines. CH_4 and N_2O emission factors are differentiated by technology and fuel, while CO_2 emission factors are differentiated only by fuel. The determination of emission factors was based on data derived from verified ETS reports and 2006 IPCC guidelines, as described in this paragraph.

CO_2 emissions from stationary combustion are estimated on the basis of fuel consumption and fuel characteristics, according to the following equation:

$$E_{CO_2} = \sum_f FC_f \cdot NCV_f \cdot CC_f \cdot OX_f \cdot 44/12$$

where, E_{CO2} is CO_2 emissions, f is an index referring to the fuel consumed, FC_f is the consumption of fuel-f, CC_f is the carbon content of fuel-f, NCV_f is the net calorific value of fuel-f and OX_f is the oxidation factor of fuel-f.

The national energy balance and the verified ETS reports are the main sources of information regarding fuel consumption by sector and activity. The basic characteristics of fuels used in the Greek energy system and the estimated CO_2 emission factors are presented in ***Table 3.13***.

Concerning the data presented in the Table 3.13, the following should be mentioned:

- The 2006 IPCC Guidelines constitute an important source of information regarding carbon content, fraction of carbon oxidised and therefore the calculated EF by fuel type. However, as indicated in Table 3.13 for the cases of refinery gas, LPG, petcoke, steamcoal, lignite, domestic and imported natural gas, either country and/or plant specific data have been used for the calculation of the respective EFs. CS EFs for gasoline, diesel and HFO are also used.
- Information on the net calorific value (NCV) per fuel is either calculated from plant or country specific data or provided by the national energy balance, compiled by the Ministry of Environment and Energy. Plant specific data were available for the following fuels: refinery gas, petcoke, steam coal and lignite, as indicated in Table 3.13. Gasoline's, HFO's and diesel's NCVs are CS, too.

- The carbon content of domestic natural gas derives from data of the company involved on the exploitation of domestic crude oil and natural gas fields. The carbon content of the domestic natural gas is higher than the one of the imported natural gas and as a result the corresponding CO_2 emission factor is higher.

Table 3.13 Carbon dioxide emission factors (in t CO_2 / TJ), net calorific value (in TJ / kt) and other parameters by fuel type (2023)

Fuel type	Net calorific value (TJ/kt)	Carbon content. CC (tC/TJ)	Oxidation factor. OF (%)	EF (tCO_2/TJ)
Liquid fuels				
Refinery gas	20.55[1]	17.40	100	63.82[1]
LPG	47.30	17.21	100	63.10[2], 68.07[3]
Propane	46.35	17.65	100	64.7249
Butane	45.75	18.09	100	66.3275
Mixture 80-20 propane - butane	46.23	17.74	100	65.0454
Mixture 70-30 propane – butane	46.17	17.78	100	65.2057
Gasoline (fossil origin)	42.79	19.98	100	73.26
Kerosene	43.80	19.61	100	71.90
Diesel oil (thermal) – fossil origin	42.80	20.12	100	73.78
Diesel oil (transport sector) – fossil origin	42.75	19,97	100	73.23
Heavy fuel oil (high S)	40.14	21.38	100	78.40
Heavy fuel oil (low S)	41.02	21.36	100	78.31
Naphtha	45.01	19.80	100	72.60
Petroleum coke	32.33[4], 31.51[5]	27.70, 24.59	100	101.58[4], 95.3651[5]
Other oil products	40.20	20.0	100	73.30
Solid fuels				
Steam coal	24.17[6]	26.34	100	96.59[6]
Lignite				
Electricity generation	5.097	36.29	98.0[10]	130.412
Industry	9.002	27.05	100	99.18
Other sectors	5.097	36.29	100	130.412
Oven and gas coke	29.31	28.91	100	106.00
BKB / Patent fuel	14.20	25.28	100	92.71
Gaseous fuels				
Natural gas – Domestic			100	53.20[7]
Natural gas – Imports			100	55.61[8], 55.65[9]
Gas works gas		12.11	100	44.4
Biofuels (fossil part)[11]				
Bio-MTBE				1.9947 kgCO2/kg
Bio-ETBE				1.7242 kgCO2/kg
Bio-TAEE				1.8928 kgCO2/kg
Biomethanol / Bioethanol				No fossil part

Biodiesel FAME		0.15246 kgCO2/kg

Notes to Table 3.13:

1 Mean value. It depends on refineries' feedstock characteristics and processes applied. It is derived from PS data contained in the verified EU ETS emission reports of refineries. Especially for the case of HBG and LBG refinery gases from flexicoker units, the EFs obtained from EU ETS reports were 2.7604 and 0.5258 tCO2/t, respectively, and the NCVs 46.75 and 4.24 TJ/kt, respectively.

2 Used in sectors other than refineries.

3 Used for petroleum refining category. It is derived from PS data contained in the verified EU ETS emission reports of refineries.

4 Mean value. Petcoke consumed in refineries. It is derived from PS data contained in the verified EU ETS emission reports of refineries.

5 Mean value. Petcoke consumed in manufacturing industries (i.e. cement, lime and ceramics plants). It is derived from PS data contained in the verified EU ETS emission reports.

6 Derived from PS data of verified EU ETS emission reports.

7 The emission factor was calculated to comprise emissions from a)the combustion of domestic gas from two different reservoirs, b)the combustion of gas by the company that extracts the domestic natural gas which derived from the Public Gas Corporation distribution network (imported gas) and c)the processing of sour gas.

8 Mean value for electricity production based on PS data derived from verified EU ETS emission reports.

9 Mean value based on chemical composition data of NG provided by DESFA (Hellenic Gas Transmission System Operator S.A.).

10 Oxidation factor is based on two studies from the Public Power Company (PPC), which were published in 1993 and 2004, respectively. Both are entitled "Estimation of the CO2 emission factors for the lignite used by the PPC", In these studies, the oxidation factor was based on measurements of the content of unoxidized carbon of wet and flying ash by-products of all lignite plants in Greece.

11 Estimated based on the methods from "Sebos, I. (2022). Fossil fraction of CO2 emissions of biofuels. Carbon Management, 13(1), 154-163. https://doi.org/10.1080/17583004.2022.2046173"

- Calorific values for gas works gas (in use until 1997) and natural gas do not appear in the table above, because the relative consumption in the energy balance is given directly in energy units (TJ).
- Domestic natural gas is produced from two reservoirs (typical values):
  1. the South Kavala reservoir, which has a NCV of 11313 kcal/Nm^3 and a carbon content of 15.68 tC/TJ.
  2. the Prinos reservoir, which has a NCV of 12192 kcal/Nm^3 and a carbon content of 16.30 tC/TJ.
- The calorific value of lignite is differentiated annually, as it is related to the characteristics of mining fields, and therefore it is presented separately in ***Table 3.14***.

Table 3.14 Net calorific value of lignite by sector (in TJ / kt) for the period 1990 – 2023

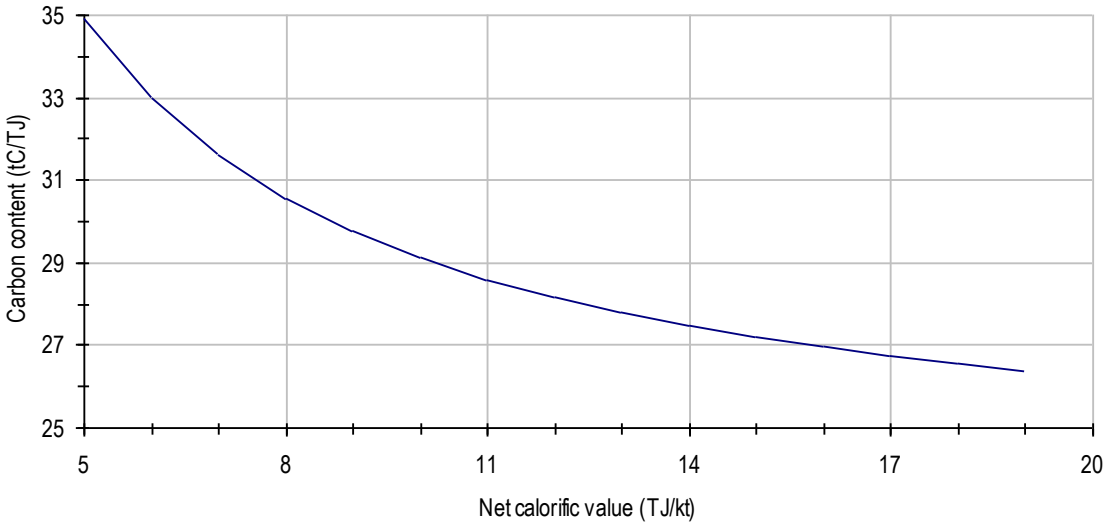
Year	Electricity generation	Industry	Other sectors

1990	5.711	8.399	5.740
1991	5.447	8.323	5.481
1992	5.225	9.504	5.288
1993	5.355	11.074	5.443
1994	5.355	11.317	5.418
1995	5.179	11.300	5.451
1996	4.915	11.204	5.037
1997	5.384	11.300	5.485
1998	5.506	11.380	5.589
1999	5.366	11.110	5.421
2000	5.346	10.902	5.388
2001	5.296	10.006	5.296
2002	5.087	8.620	5.296
2003	5.043	10.886	5.002
2004	5.182	9.807	5.109
2005	5.240	10.471	5.200
2006	5.240	10.471	5.280
2007	5.297	10.235	5.297
2008	5.179	8.025	5.179
2009	5.141	7.435	5.275
2010	5.497	8.025	5.419
2011	5.388	8.479	5.356
2012	5.337	8.501	5.350
2013	5.388	8.205	5.224
2014	5.337	8.205	5.257
2015	5.388	10.077	5.160
2016	5.337	9.140	5.096
2017	5.338	9.213	5.068
2018	4.905	9.135	4.905
2019	4.842	8.928	4.842
2020	4.857	9.002	4.857
2021	4.860	8.497	4.860
2022	4.873	9.002	4.873
2023	5.097	9.002	5.097

- A country specific carbon content of lignite used for electricity production was used in emission calculations for the period 1990-2005 (33.95 tC/TJ), which is based on two studies of the Public Power Corporation (PPC 1993 and PPC 2004). For the period 2006-2023 plant specific values for CC were used, based on verified EU-ETS reports, ranging from 33.74 to 36.33 tC/TJ. These values lie out of the range suggested by the 2006 IPCC Guidelines. However, given that the net calorific value of the Greek lignite is one of lowest (see Papanicolaou et al., 2004 for an overview of the properties of the Greek lignites) a high value for the carbon content is expected. Moreover, according to international literature (Fott, 1999)

the suggested value by IPCC corresponds to a net calorific value of 13 TJ / kt, which is not representative of national circumstances (see Table 3.14 and Figure 3.5).

- The oxidation factor 98% is used for the combustion of lignite for electricity production. This is based on the above-mentioned studies of the Public Power Corporation (PPC 1993, and PPC 2004).
- The NCV and EF used for Electricity generation are mean values of lignite that is mined from various mining fields, located in 5 different locations in Greece (scattered both to north and south Greece). The lignite used in Industry originates mainly from a single mining field. The quality of lignite from this mining field is superior than the others used for Electricity generation. For that reason, the NCV is greater and the EF is lower of lignite used in Industry compared to the mean values of the ones used for Electricity production. The inter-annual variation in the NCV of the coals used in manufacturing industries stems from the fact that they are used in small quantities and are mixed with coals of other origin.
- Based on chemical composition data of natural gas provided by DESFA (Hellenic Gas Transmission System Operator S.A.) a country specific CO2 EF of NG per year was calculated. Especially for the public electricity and heat sector and for the years 2005-2022, a CO2 EF of NG, based on plant specific data (ETS reports), was also calculated (plant specific EF).



Source : Fott. P.. (1999). Environmental Science & Policy. 2

Figure 3.5 The relationship between the net calorific value and the carbon content of lignite

For the estimation of CH_4 and N_2O emissions (as well as of other gases) from stationary combustion a Tier 1 methodology with 2006 IPCC defaults emission factors was applied.

Further analysis of fuel consumption by technology is presented hereafter.

3.2.4.3 Energy industries (CRT Source Category 1A1)

3.2.4.3.1 Source category description and methodological issues

Public electricity and heat production (CRT Source Category 1.A.1.a)

Electricity production in Greece increases continuously at an average annual rate of 3.4% for the period 1990 – 2008. For the years 2009-2010, it decreases at an average annual rate of 5.1% and increases at an average annual rate of 3.1% in 2011 and 2012. For years 2013 – 2014, it decreased by an average annual rate of 8.9%; and for years 2015-2017, it increased by an average annual rate of 3.1%. In 2020, it decreased by 12.7% compared to 2017. Gross electricity production in 2023 (49.9 TWh) was approximately 42.61% higher compared to 1990 levels (***Figure 3.6***).

Electricity generation from the use of fossil fuels was approximately 52.0% of electricity production in 2023. Specifically, 9.2% of electricity is produced by solid fuels (lignite), while the share of liquid fuels (diesel, heavy fuel oil and refinery gas) and natural gas is 9.3% and 32.0% respectively. The rest of electricity production, i.e. around 48.0%, derives from renewable energy sources as hydropower, wind energy, PVs and biogas.

The calculation of GHG emissions from this sector was performed as described in section 3.2.4.2. The allocation of energy consumption by technology was made on the basis of Public Power Corporation (PPC) verified EU ETS reports on the installed capacity and the characteristics of electricity production plants. Therefore:

- Electricity production from lignite is produced exclusively by steam turbines.
- Natural gas is used mainly in combined cycle units and secondarily in gas turbines.
- Heavy fuel oil is used in gas turbines and in internal combustion engines (only in the islands' electricity systems).
- Diesel is used in gas turbines and in internal combustion engines in the islands' electricity systems.

GHG emissions from electricity and heat production for the period 1990 – 2023 are presented in ***Table 3.15***.

GHG emissions from electricity generation in 20223 decreased by 62.3% compared to 1990 levels. During the period 1990-2007, an increasing trend of emissions was observed. This increase was attributed to the high increase of electricity demand in Greece as well as to the structural characteristics of the Greek electricity generation system. It should be mentioned that the availability of hydroelectric plants has a significant effect to emissions trends. For instance, the significant increase of electricity demand in 1999 (by 3.3% compared to 1998) was not followed by a similar increase of emissions (1.3%) because of the penetration of natural gas and the high availability of hydroelectric plants. On the contrary, electricity generation from hydroelectric plants

in 2000 decreased by 14% compared to 1999, while energy demand increased by 6.2% and as a result fossil fuels consumption and GHG emissions increased accordingly.

During the period 2008-2023, a decreasing trend of emissions was observed. This decrease is attributed to the increasing share of NG and RES in the Greek energy system, along with a decrease in electricity consumption during the last years, as a result of energy efficiency measures and the economic recession that the country is facing. In 2017, GHG emissions were increased by 11.4% compared to 2016, which is attributed to a 12.2% increase of solid fuels use in 2017 compared to 2016. In 2019, the emissions were decreased by 17.9% compared to 2018, which is attributed to the reduced use of solid fuels and the increase of electricity imports (about 58% increase of net imports in 2019 compared to 2018). A further 26.8% reduction of GHG emissions was also observed in 2020 compared to 2019, due to the gradual phasing-out of lignite-fired power plants. Despite electricity production remaining roughly the same in 2022 as it was in 2021, GHG emissions saw a reduction of 6.4%, due to increase in the share on renewable energy sources. Following the decreasing trend, in 2023 GHG emissions further decreased by 18.6%.

CO_2 emissions in 2023 accounted for 99.75% of total emissions from public electricity and heat production, while emissions from solid fuels consumption accounted for 39.66% of total emissions in 2023. However, due to the penetration of natural gas and RES technologies, total emissions per electricity produced by fossil fuels have a decreasing trend.

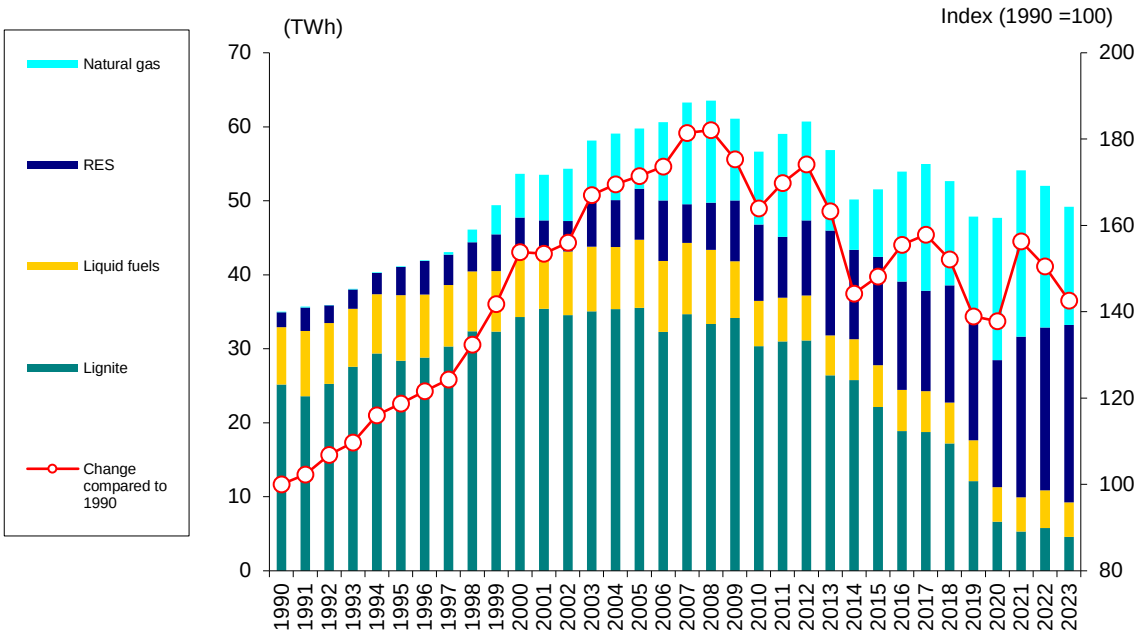


Figure 3.6 Electricity production (in TWh) by energy type for the period 1990 – 2023

Petroleum refining (CRT sector 1.A.1.b)

The inventory for the sector of petroleum refining includes emissions from the production of heat, steam and/or electricity in furnaces, gas turbines and internal combustion engines within the

refineries as well as emissions from thermal cracking of heavy hydrocarbons. Additionally, emissions from fluid catalytic cracking/CO boiler, flaring and production of chemicals, such as hydrogen, are also included. Hydrogen production, where natural gas is used as feedstock, is accounted in the Industrial Processes sector.

GHG emissions from refineries (***Table 3.16***) are calculated on the basis of fuel consumption, which is obtained from the national energy balance and plant specific data derived from verified ETS reports and the estimated CO2 emission factors described previously (section 3.2.4.2).

For, the estimation of CH_4 and N_2O emissions from refineries, a Tier 1 methodology with 2006 IPCC defaults emission factors on the basis of fuel consumption was applied.

The total increase of GHG emissions from refineries in 2023, compared to 1990 levels, is estimated at 133.0%. This increasing trend is a result of the increased production levels, and the requirements for the production of sulphur-free fuels (sulphur content less than 10 ppm) set by EU Directives.

Verified activity data and CO2 EFs from plant reports under EU ETS were used for the estimation of emissions of 1A1b category. Interannual changes of the CO2 implied emission factor (IEF) of liquid fuels can be attributed to the variation of the fuel mix used by the four refineries that are located in Greece. The interannual change of CO2 IEF between 2012 and 2013 was associated with the CO2 EF of refinery gas. The weighted average EF of refinery gas increased from 56.69 t/TJ in 2012 to 64.55 t/TJ in 2013. This was a result of the recently upgrade project, worth €1.4 billion, that took place in one of the 4 refineries. The upgrade, among others, includes the installation of a high pressure hydrocracking unit (hydrocracker) with a capacity of 39,000 bbl/d and a thermal cracking unit (flexicoker). The flexicoker produces a refinery gas (LBG) with a higher EF compared to other refinery gases (around 120 tCO2/TJ).

Table 3.15 GHG emissions from public electricity and heat production per gas and fuel type and total emissions for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2 emissions (in Mt)																					
Liquid fuels	5.42	5.86	5.77	5.91	5.79	6.26	6.16	5.97	5.80	6.01	6.43	5.98	5.87	6.44	5.76	6.34	6.48	6.64	6.95	5.33	3.99
Solid fuels	35.20	33.59	36.04	35.83	37.74	36.02	35.05	38.51	40.47	39.73	42.21	43.17	42.40	42.89	44.43	44.40	40.73	42.57	41.21	41.18	39.68
Gaseous fuels								0.11	0.79	1.97	2.88	2.86	3.05	3.39	3.68	3.57	4.26	5.69	5.72	4.17	4.64
CH_4 emissions (in kt)																					
Liquid fuels	0.21	0.23	0.23	0.23	0.23	0.24	0.24	0.23	0.23	0.23	0.25	0.23	0.23	0.25	0.23	0.25	0.25	0.26	0.27	0.21	0.16
Solid fuels	0.29	0.28	0.30	0.29	0.31	0.30	0.29	0.32	0.33	0.33	0.35	0.35	0.35	0.35	0.36	0.36	0.33	0.35	0.34	0.34	0.32
Gaseous fuels								0.00	0.01	0.04	0.05	0.05	0.06	0.06	0.07	0.06	0.08	0.10	0.10	0.08	0.08
N_2O emissions (in kt)																					
Liquid fuels	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.03
Solid fuels	0.43	0.41	0.44	0.44	0.46	0.44	0.43	0.47	0.50	0.49	0.52	0.53	0.52	0.53	0.55	0.55	0.50	0.52	0.51	0.50	0.48
Gaseous fuels								0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
TOTAL (Mt CO_2 eq)	**40.77**	**39.60**	**41.97**	**41.90**	**43.69**	**42.43**	**41.37**	**44.76**	**47.24**	**47.88**	**51.72**	**52.20**	**51.51**	**52.92**	**54.07**	**54.51**	**51.65**	**55.09**	**54.07**	**50.86**	**48.49**

NO: Not Occurring. The use of natural gas for electricity generation started in 1997.

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO_2 emissions (in Mt)													
Liquid fuels	3.78	3.81	3.40	3.51	3.66	3.64	4.03	3.63	3.60	3.08	3.15	3.25	3.09
Solid fuels	40.71	41.99	36.11	33.95	28.75	22.43	24.73	23.28	16.60	9.10	8.30	8.25	6.07
Gaseous fuels	5.97	5.10	4.59	2.98	3.08	5.24	6.11	6.27	7.04	7.76	8.67	7.34	6.17
CH_4 emissions (in kt)													
Liquid fuels	0.15	0.15	0.14	0.14	0.14	0.14	0.16	0.14	0.14	0.12	0.12	0.13	0.12
Solid fuels	0.32	0.33	0.29	0.28	0.24	0.18	0.20	0.20	0.14	0.07	0.06	0.06	0.05
Gaseous fuels	0.11	0.09	0.08	0.05	0.06	0.09	0.11	0.11	0.13	0.14	0.16	0.13	0.11
N_2O emissions (in kt)													
Liquid fuels	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.02
Solid fuels	0.48	0.50	0.44	0.41	0.36	0.27	0.31	0.29	0.21	0.11	0.10	0.09	0.07
Gaseous fuels	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
TOTAL (Mt CO_2 eq)	**50.63**	**51.08**	**44.25**	**40.59**	**35.62**	**31.41**	**34.99**	**33.28**	**27.33**	**20.00**	**20.17**	**18.88**	**15.37**

Table 3.16 GHG emissions from petroleum refineries for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2 (kt)	2375	2374	2306	2285	2458	2484	2722	2772	2850	2584	3103	3148	3255	3106	3258	3656	4331	4380	4047	3714	3669
CH_4 (kt)	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.11	0.11	0.10	0.09	0.09
N_2O (kt)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01
TOTAL (kt CO_2 eq)	**2380**	**2379**	**2311**	**2289**	**2463**	**2488**	**2727**	**2777**	**2855**	**2589**	**3109**	**3154**	**3261**	**3112**	**3264**	**3663**	**4338**	**4388**	**4054**	**3721**	**3675**

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO_2 (kt)	3333	3560	5063	5305	5253	5562	4904	4930	4600	4448	5277	5841	5534
CH_4 (kt)	0.08	0.09	0.12	0.11	0.11	0.12	0.10	0.10	0.09	0.09	0.11	0.12	0.11
N_2O (kt)	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02
TOTAL (kt CO_2 eq)	**3339**	**3566**	**5072**	**5313**	**5261**	**5570**	**4912**	**4937**	**4606**	**4454**	**5284**	**5850**	**5542**

Other energy industries (CRT Source Category 1.A.1.c)

The inventory for the other energy industries includes GHG emissions from the combustion of natural gas during oil and gas extraction.

Data collected during the formulation of the NAP for the period 2005 – 2007 and verified ETS reports (for years 2005 – 2023) were used in this inventory. GHG emissions (***Table 3.17***) are calculated on the basis of the consumption of natural gas and the emission factors as described previously. To be stated that the CO2 EF of natural gas was estimated to comprise emissions from the processing of sour gas, based on data derived from verified ETS reports.

GHG emissions from the other energy industries in 2023 decreased by approximately 64.6% compared to 1990. The annual variation of emissions is related to the changes of the primary production of crude oil and natural gas.

Table 3.17 GHG emissions (in kt CO_2 eq) from other energy industries for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Emissions (in kt CO_2 eq)																					
CO_2	102.0	108.5	94.2	89.5	103.1	98.6	103.9	110.4	83.6	6.2	104.0	98.9	104.3	90.3	109.0	91.2	97.0	93.6	88.9	86.0	48.9
CH_4	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.00	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.02
N_2O	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.04	0.00	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.04	0.03
TOTAL	**102.1**	**108.6**	**94.2**	**89.6**	**103.2**	**98.7**	**104.0**	**110.5**	**83.7**	**6.2**	**104.1**	**98.9**	**104.4**	**90.4**	**109.1**	**91.2**	**97.1**	**93.6**	**89.0**	**86.1**	**49.0**

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Emissions (in kt CO_2 eq)													
CO_2	46.0	45.4	41.6	33.2	30.2	35.9	37.0	45.0	43.4	34.2	26.01	4.22	36.08
CH_4	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00
N_2O	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.00	0.00
TOTAL	**46.0**	**45.4**	**41.6**	**33.3**	**30.2**	**36.0**	**37.0**	**45.0**	**43.4**	**34.2**	**26.1**	**4.2**	**36.12**

3.2.4.3.2 Recalculations

No recalculation was performed in 2025 submission.

3.2.4.4 Manufacturing industries and construction (CRT Source Category 1.A.2)

3.2.4.4.1 Source category description and methodological issues

Emissions from energy consumption for the production of steam and process heat are mainly reported under Manufacturing industry and construction.

Data collected (through questionnaires) during the formulation of the NAP for the period 2005 – 2007 and verified installation ETS reports of 2005 – 2023 provided significant information regarding the structure of energy demand in industry per activity / technology. Energy consumption in activities not included in the EU emissions trading scheme (e.g. grey iron foundries) is estimated on the basis of the official data (national energy balance).

The calculation of GHG emissions from this sector was performed as described in section 3.2.4.2. The assumptions made for the estimation of GHG emissions for the period 1990 – 2023 (***Table 3.18***) are the following:

- The energy consumption in the energy balance sector *Iron & Steel* is allocated to steel production (exclusively in electric arc furnaces) and grey iron foundries.

  Plant specific data on energy consumption for steel production cover the period 1990 – 2003 and 2005 – 2023. According to those data natural gas represents the main fuel consumed while the consumption of other fuels includes small quantities of heavy fuel oil, LPG and diesel oil. The specific consumption for steel production has decreased from 3.6 GJ / t steel in 1990 to 1.6 GJ / t steel in 2003. For 2004, it was assumed that unit consumption decreased further to 1.5 GJ / t steel while heavy fuel oil, LPG and diesel oil consumption remained constant at 2003 levels. For 2005 – 2023 activity data were available through the verified ETS reports. Emission factors as described previously were applied.

- Primary aluminium production and ferroalloys production are included, among others, in the energy balance sector of *Non-ferrous metals*.

  The available plant specific energy consumption data (heavy fuel oil) refer only to primary aluminium production and cover the years 1990 and 1998 – 2003 and 2005 – 2023. On the basis of those data an average specific consumption is estimated (heavy fuel oil consumption per aluminium produced) which is used for the estimation of energy consumption for the period 1991 – 1997. The specific consumption for 2004 is kept constant at 2003 levels. For 2005 – 2023 plant specific energy consumption data were available through the verified ETS reports.

  The rest of the energy consumption in the sector (according to the energy balance data) refers exclusively to steam production in boilers.

  The emissions from the non-energy use of solid fuels for ferroalloys production were reallocated to the industrial processes sector (2.C.2) as from 2010 submission

- Energy consumption reported in the energy balance under *Chemicals*, *Paper, pulp and print* and *Food and Tobacco* refers exclusively to steam production in boilers.

- The rest of the industrial sectors are included in Other industries (1.A.2f instead of 1.A.2g in the CRT tables). With the exception of *Mining* and *Non-metallic minerals*, energy consumption refers exclusively to steam production in boilers.

  Energy consumption in *Mining* refers to internal combustion engines and therefore CH_4 and N_2O emissions are estimated using the respective 2006 IPCC default emission factors.

Energy consumption in Non-metallic minerals is disaggregated into energy consumption for cement production, lime production, ceramics production and glass production according to verified ETS reports of years 2005 – 2023.

GHG emissions from manufacturing industries and construction are closely related to industrial activity trends. However, it should be noted that in cases of major industrial units, variations in emissions should be attributed to the realization of investments for the modernization of the installations and for capacity expansion.

Overall, GHG emissions from industry in 2023 decreased by 53.75% compared to 1990.

Inter-annual changes of the CO2, CH4 or N2O implied emission factors (IEFs) depend on the fuel mix used by the industries of this category. For example, in 2013 the percentage of petcoke (which is considered to be a liquid fuel according to IPCC Gls) of the fuel mix was higher than 2012. As a result, an increase of the CO2 IEFs was observed between 2012/2013 (from 82.00 t/TJ to 87.09 t/TJ). The inter-annual variation of the CO2 EF between 2003/2004 is explained by the same reason.

3.2.4.4.2 Recalculations

No recalculation was performed in 2025 submission.

Table 3.18 GHG emissions (in kt) from manufacturing industries and construction for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Iron and Steel											
CO_2	447.32	432.65	430.13	380.56	370.14	356.02	262.40	286.40	272.49	318.84	286.42
CH_4	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non Ferrous											
CO_2	582.21	711.77	707.28	690.42	663.00	673.97	702.83	692.99	785.48	902.71	935.90
CH_4	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03
N_2O	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01
Chemicals											
CO_2	807.80	622.40	505.65	547.52	487.73	602.61	874.31	839.83	917.10	548.34	649.13
CH_4	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02
N_2O	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00
Pulp Paper and print											
CO_2	306.05	291.47	284.28	268.62	253.38	213.18	292.34	343.72	308.68	317.61	377.28
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food processing											
CO_2	916.84	942.51	951.79	970.21	929.84	946.20	1016.37	983.52	1069.94	972.35	1096.77
CH_4	0.03	0.03	0.03	0.03	0.03	0.03	0.23	0.23	0.24	0.23	0.28
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.04
Other											
CO_2	6278.26	6387.00	6165.54	5903.01	5906.08	6689.92	6939.35	7048.49	6798.49	6079.92	6502.25
CH_4	0.38	0.37	0.37	0.36	0.35	0.38	0.20	0.20	0.18	0.17	0.18
N_2O	0.16	0.16	0.16	0.15	0.16	0.18	0.18	0.19	0.18	0.16	0.19
TOTAL	**9404.85**	**9454.27**	**9110.42**	**8824.82**	**8674.68**	**9553.42**	**10169.30**	**10278.31**	**10232.23**	**9212.49**	**9932.568**

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Iron and Steel										
CO_2	311.30	324.94	305.69	230.37	185.86	174.29	200.12	190.46	160.48	160.29
CH_4	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non Ferrous										
CO_2	928.15	975.37	1012.18	977.70	816.18	831.62	825.06	747.33	538.50	507.91
CH_4	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01
N_2O	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Chemicals										
CO_2	591.64	529.78	648.65	914.53	781.25	758.14	617.16	750.30	806.09	977.93
CH_4	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.03
N_2O	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Pulp Paper and print										
CO_2	347.13	357.17	367.54	254.10	231.01	270.78	257.47	241.55	198.58	179.81
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food processing										
CO_2	1002.00	1047.87	1100.61	882.98	797.05	854.19	711.12	657.43	592.88	502.90
CH_4	0.27	0.29	0.25	0.26	0.29	0.26	0.26	0.31	0.29	0.28
N_2O	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Other										
CO_2	6791.51	6190.91	5668.10	5358.68	7323.02	7480.06	7348.19	6738.69	5140.25	4484.41
CH_4	0.18	0.17	0.15	0.14	0.22	0.21	0.20	0.19	0.15	0.14
N_2O	0.19	0.18	0.17	0.18	0.24	0.26	0.25	0.27	0.24	0.20
TOTAL	**10056.79**	**9509.45**	**9179.91**	**8696.95**	**10236.09**	**10474.23**	**10060.03**	**9434.69**	**7536.08**	**6898.61**

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Iron and Steel													
CO_2	149.26	198.42	172.76	148.06	65.04	120.73	102.57	90.78	95.83	94.28	116.4	123.1	87.90
CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non Ferrous													
CO_2	466.12	532.10	772.21	622.90	587.07	562.22	759.08	321.52	357.58	335.37	673.92	557.9	620.05
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemicals													
CO_2	807.61	669.75	342.96	356.93	443.54	92.03	266.25	478.34	452.17	617.91	645.19	217.4	383.35
CH_4	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pulp Paper and print													
CO_2	151.75	118.99	138.34	133.24	104.37	79.66	76.89	91.28	92.93	84.33	86.45	83.91	98.45
CH_4	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food processing													
CO_2	404.06	510.77	568.35	645.79	620.39	630.34	636.66	607.52	580.78	555.01	611.45	624.54	640.29
CH_4	0.29	0.22	0.13	0.16	0.20	0.15	0.15	0.16	0.15	0.17	0.12	0.12	0.14
N_2O	0.04	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Other													
CO_2	2938.25	3427.75	3234.54	3490.41	3345.87	3806.95	3874.52	3459.37	2989.23	2718.64	2646.65	2789.3	2468.48
CH_4	0.12	0.12	0.10	0.12	0.12	0.12	0.14	0.18	0.20	0.20	0.26	0.26	0.25
N_2O	0.14	0.16	0.15	0.20	0.22	0.19	0.19	0.20	0.12	0.10	0.11	0.23	0.12
TOTAL	**4983.47**	**5525.67**	**5287.79**	**5472.45**	**5249.74**	**5361.50**	**5787.20**	**5125.22**	**4619.37**	**4453.72**	**4828.45**	**4473,67**	**4347.29**

3.2.4.5 Other sectors (CRT Source Category 1.A.4)

3.2.4.5.1 Source category description and methodological issues

Residential – Tertiary sector (CRT Source Category 1.A.4 a and b)

GHG emissions from the residential – tertiary sector result from energy consumption for heat in order to cover the needs for the space heating, water heating etc. Thermal needs in these sectors are covered mainly by liquid fossil fuels, while the contribution of biomass (fuel wood), especially in the residential sector, is also significant. The penetration of natural gas to the fuel mixture has an increasing trend.

The activity data of biomass consumption for the whole time-series were obtained from the national energy balance.

Two basic technologies are considered: central heating boilers, and other stationary equipment (e.g. oil stoves, fireplaces etc.). For the allocation of fuel consumption by technology, it is assumed that the consumption of diesel, heavy fuel oil, gas works gas (until 1997) and natural gas concern central heating boilers and the consumption of the rest of the fuels concern the other stationary equipment.

GHG emissions (***Table 3.19*** for the residential sector and ***Table 3.20*** for the commercial/ institutional sector) are calculated on the basis of fuel consumption as it is presented in Annex II, the emission factors of CO_2 presented in Table 3.13 and default 2006 IPCC EF for CH_4 and N_2O as in the previous categories of stationary combustion (s. section 3.2.4.2).

GHG emissions from the residential and the commercial/institutional sector in 2006 increased substantially compared to 1990 levels, as a result of the great increase of liquid fuel consumption since 1996, according to the national energy balance. However, a decreasing trend of the last years is attributed to the penetration of natural gas to the fuel mixture, the increasing use of biomass and the economic recession (in the economic recession years post 2007). The GHG emissions of residential sector in 2023 were decreased compared to 1990 levels by 21.54%, while the emissions of tertiary sector increased by about 24.7% compared to 1990.

Agriculture (CRT Source Category 1.A.4c)

GHG emissions from agriculture result from combustion activities are related to heating needs (e.g. space heating in greenhouses) and to agricultural machinery. Fuel consumption is not allocated to forestry or fisheries since the available information does not allow for such a disaggregation.

Energy needs are covered by diesel and heavy fuel oil in boilers and by lignite and biomass in other stationary equipment. Agricultural machinery uses diesel oil and gasoline. The distribution of

diesel consumption between thermal needs and machinery is kept constant during the whole period 1990 – 2023.

GHG emissions (***Table 3.21***) are estimated on the basis of fuel consumption as it is presented in Annex II, CO_2 emission factors presented in Table 3.13 and default 2006 IPCC EF for CH_4 and N_2O as in the previous categories of stationary combustion (s. section 3.2.4.2).

The majority of GHG emissions from agriculture are attributed to agricultural machinery.

3.2.4.5.2 Recalculations

No recalculation was performed in 2025 submission.

Table 3.19 GHG emissions (in kt) from the residential sector for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2	4654	4730	4634	4600	4628	4853	6579	6883	7218	7060	7653	8236	8531	10137	9698	9960	9631	8676	8466	7476	6742
CH_4	9.15	9.26	9.25	9.24	9.24	9.21	9.26	9.30	9.22	9.09	9.12	9.11	8.98	8.97	8.99	8.96	8.94	9.62	7.87	6.91	7.19
N_2O	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.15	0.13	0.13

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO_2	7979	7014	3588	3781	5050	4687	4696	3973	4461	4999	4549	5023	3595
CH_4	9.50	11.49	9.78	9.50	9.98	8.66	8.84	8.36	8.09	7.62	8.22	8.56	8.99
N_2O	0.16	0.19	0.15	0.14	0.16	0.14	0.14	0.13	0.13	0.12	0.13	0.13	0.13

Table 3.20 GHG emissions (in kt) from the commercial / institutional sector for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2	519	687	637	606	621	666	807	780	795	768	785	1021	1039	1141	1232	1549	1611	1512	1508	1240	1150
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO_2	1085	1353	829	561	713	695	711	683	734	583	624	612	647
CH_4	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.21 GHG emissions (in kt) from agriculture for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2	2893	3032	2814	2737	2750	2559	2609	2600	2600	2610	2612	2647	2874	3078	2630	2705	2863	2541	2480	1959	1682
CH_4	0.39	0.40	0.38	0.38	0.38	0.37	0.37	0.37	0.37	0.38	0.40	0.37	0.39	0.41	0.41	0.45	0.43	0.44	0.41	0.44	0.41
N_2O	1.03	1.07	0.99	0.98	0.98	0.91	0.92	0.92	0.92	0.92	0.92	0.93	1.03	1.12	0.95	0.97	1.01	0.90	0.88	0.69	0.62

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
CO_2	1739	890	486	469	499	431	458	463	450	703	557	589	500
CH_4	0.51	0.98	0.49	0.39	0.41	0.39	0.43	0.41	0.43	0.40	0.37	0.45	0.44
N_2O	0.66	0.09	0.12	0.14	0.15	0.12	0.12	0.13	0.12	0.21	0.16	0.16	0.13

3.2.4.6 Uncertainties and time-series consistency

In general, the uncertainty of emissions of the stationary combustion sector is relatively small. The uncertainty associated with activity data –i.e. fuel consumption- is less than 5%, since the AD are obtained from the national energy balance and are cross-checked with data from other sources (e.g. plant specific data from major industrial installations). On the other hand, the uncertainty associated with emission factors is also very low for the case of CO2, less than 5%, since plant and country specific EFs are mainly applied. For the case of CH4 and N2O EFs, the uncertainty is higher, about 100 and 300% respectively, since IPCC defaults emission are applied. The results of uncertainty analysis are presented in ***Table 1.9***. The detailed calculations of uncertainty are presented in Annex IV (***Tables IV.1 – IV.3***).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data in line with IPCC guidelines. In case of changes or refinements in methodologies and EFs based on plant-specific data, e.g. from the European Union emissions trading scheme (EU ETS) reports, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

3.2.4.7 Source-specific QA/QC and verification

The following source-specific QC procedures are applied to the stationary combustion sector. These procedures are based on the plant specific data that become available through the EU ETS reports. To be mentioned that EU ETS reports have been both verified by external verification bodies and reviewed by the competent authorities of Ministry of Environment and Energy (MEEN).

1. **Activity data comparison**: Cross-checking between energy consumption data derived from national energy balance and plant specific energy consumption data of major industrial plants derived from verified ETS reports is performed. The findings of the above quality check are communicated to the competent department of MEEN that is the compiler of national energy balance. By this way both the national energy balance and the energy consumption used in emission calculations is verified and improved.

2. **Emissions comparison**: Verified ETS reports were used for the computation of plant specific CO2 EFs and NCVs. For quality control purposes emissions calculated by applying PS EFs and NCVs are compared with the emissions calculated by using IPCC defaults EFs and NCVs derived from energy balance.

3.2.4.8 Recalculations

No recalculation was performed in 2025 submission.

3.2.4.9 Planned improvements

Based on the findings of internal inventory reviews described in section 1.6, EU internal audits and UNFCCC ERT reviews, actions are being planned and executed that lead to recalculations / improvements of the stationary combustion GHG emission inventory.

3.2.5 Transport (CRT Source Category 1.A.3)

3.2.5.1 Source category description

Internal aviation, road transportation, railways and internal navigation are included in the transport sector. Emissions from international marine and aviation bunkers are not included in national totals but are calculated and reported separately as Memo items.

In 2023, in total, GHG emissions from transport (***Tables 3.22(a,b,c,d)***) increased by approximately 20.92% compared to 1990 emissions (from 14.50 Mt CO2 eq in 1990 to 17.54 Mt CO2 eq in 2023).

In 2023, the majority of GHG emissions derived from road transport, the contribution of which increased from 83% in 1990 to approximately 85% of total emissions of the sector ***(Tables 3.24(a,b,c,d))***, as a result of two contradictory parameters: a) the significant increase of the number of vehicles in the country and b) the considerable progress in antipollution technology of the vehicles engines.

The share of internal navigation in the emissions of the transport sector fluctuated from 13% in 1990 to 12.4% in 2023 (Tables 3.25(a,b,c,d)). Additionally, internal aviation has a contribution of the order of 2.4% in 2023 (Table 3.26d), while the contribution of railways is about 0.08% in 2023 (Tables 3.27(a,b,c,d)). The contribution of other transport (pipeline transportation) is negligible.

Tables 3.22(a) GHG emissions, air pollutants emissions and energy consumption in the transportation sector for the period 1990 – 1999

Table 3.22(a)	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fuel Consumption	TJ	191948.56	202802.31	207727.16	210177.96	214034.01	218617.39	224926.91	234194.51	257446.88	261678.81
Emissions											
CO_2	Kt	14136.62	14932.09	15294.12	15460.88	15753.14	16084.99	16535.05	17236.86	18998.77	19311.12
CH_4	Kt	4.42	4.46	4.41	4.46	4.45	4.50	4.52	4.60	4.76	4.89
N2O	Kt	0.91	0.96	1.03	1.13	1.20	1.24	1.22	1.32	1.58	1.62
NOx	Kt	180.55	182.71	184.05	184.93	188.20	179.04	176.25	184.33	203.80	204.90
CO	Kt	877.57	848.63	799.60	804.89	787.08	700.14	693.68	690.57	692.46	689.51
NMVOC	Kt	139.17	137.53	132.81	133.53	131.53	120.75	120.09	120.06	120.66	120.27
SO_2	Kt	38.70	38.70	41.00	38.23	42.75	32.08	30.64	37.74	52.57	56.44

Tables 3.22(b) GHG emissions, air pollutants emissions and energy consumption in the transportation sector for the period 2000-2009

Table 3.22(b)	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fuel Consumption	TJ	249797.95	261133.76	265836.03	280515.97	285712.31	290003.11	300998.60	311446.24	301376.09	339912.21
Emissions											
CO_2	kt	18364.24	19227.92	19553.34	20628.46	21024.82	21333.01	22004.63	22639.51	21983.51	24796.63
CH_4	kt	4.92	5.05	4.98	4.95	4.99	4.88	4.80	4.58	4.30	4.10
N_2O	kt	1.16	1.30	1.29	1.27	1.32	1.32	1.41	1.37	1.34	1.21
NOx	kt	183.33	195.32	189.81	189.43	194.55	187.67	193.17	188.52	179.38	191.09
CO	kt	640.31	637.71	598.59	577.62	565.29	499.66	517.59	453.68	404.06	383.63
NMVOC	kt	107.07	105.72	99.23	94.19	90.21	79.58	77.15	70.39	61.92	60.01
SO_2	kt	21.32	28.69	25.06	26.67	31.66	27.77	30.41	27.43	23.30	46.72

Tables 3.22 (c) GHG emissions, air pollutants emissions and energy consumption in the transportation sector for the period 2010-2019

Table 3.22(c)	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fuel Consumption	TJ	305040.54	274497.83	229406.13	227279.99	228116.12	236510.35	241477.51	239400.32	241602.97	247961.37
Emissions											
CO_2	kt	22045.52	19771.67	16465.15	16246.67	16267.36	16801.61	17129.16	16901.58	17129.04	17519.81
CH_4	kt	4.33	3.77	3.21	3.21	3.05	2.95	2.80	2.72	2.72	2.67
N_2O	kt	1.06	0.82	0.63	0.63	0.67	0.72	0.78	0.79	0.81	0.81
NOx	kt	147.82	129.72	100.84	116.63	115.24	114.53	116.92	121.89	121.85	128.23
CO	kt	324.75	293.87	261.80	245.07	267.57	236.14	203.23	204.79	194.80	191.53
NMVOC	kt	47.77	41.73	36.95	42.64	43.70	40.42	36.77	33.84	32.09	31.65
SO_2	kt	11.25	11.19	8.37	9.33	9.45	11.19	11.62	11.88	12.78	13.15

Tables 3.22 (d) GHG emissions, air pollutants emissions and energy consumption in the transportation sector the period 2020-2023

Table 3.22(d)	Unit	2020	2021	2022	2023
Fuel Consumption	TJ	214500.39	234072.19	251372.64	246634.68
Emissions					
CO_2	kt	15040.88	16439.59	17622.64	17253.00
CH_4	kt	2.20	2.43	2.49	2.34
N_2O	kt	0.65	0.74	0.82	0.82
NOx	kt	109.95	112.52	121.89	117.72
CO	kt	172.40	165.98	165.92	160.02
NMVOC	kt	28.41	27.17	27.32	26.54
SO_2	kt	10.61	11.72	12.76	12.85

3.2.5.2 Methodological issues

Road transportation

Emissions from road transport are calculated either from a combination of total fuel consumption data and fuel properties or they result from a combination of specific emission factors and road traffic data.

Carbon dioxide emissions calculations from road transport are based on the consumption of gasoline, diesel, LPG and natural gas and the carbon content of the fuels consumed. For the estimation of emissions from road transportation, except CO_2, the newer version of COPERT, (COPERT 5.8, Computer programme to calculate emissions from road transport - Users Manual, D. Gkatzoflias, L. Ntziachristos and Z. Samaras (LAT/AUTH), 2007, ETC-ACC European Topic Centre on Air and Climate Change), was applied. COPERT is an MS Windows software program aiming at the calculation of air pollutant emissions from road transport. The technical development of COPERT is financed by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre on Air and Climate Change. Since 2007, the European Commission's Joint Research Centre has been coordinating and financing the further scientific development of the model. In principle, COPERT has been developed for use from the National Experts to estimate emissions from road transport to be included in official annual national inventories.

The methodology applied is also part of the EMEP/CORINAIR Emission Inventory Guidebook. The Guidebook, developed by the UNECE Task Force on Emissions Inventories and Projections, is intended to support reporting under the UNECE Convention on Long-Range Transboundary Air Pollution and the EU directive on national emission ceilings. The COPERT 5.8 methodology is fully consistent with the Road Transport chapter of the Guidebook. The use of a software tool to calculate road transport emissions allows for a transparent and standardized, hence consistent and comparable data collecting and emissions reporting procedure, in accordance with the requirements of international conventions and protocols and EU legislation.

Basic data requirements for the application of the model include: (a) energy consumption by fuel type, (b) fuel characteristics, (c) the number of vehicles per vehicle category, engine size or weight and emission control technology, (d) other parameters such as: the mileage per vehicle class and per road class, the average speed per vehicle type and per road (urban, rural and highway) and (e) climatic conditions. The energy consumption as well as the associated emissions are calculated based on those data and a number of equations described in Ntziachristos and Samaras (2000).

It should be noted here that COPERT 5.8, is a simulation model for road transport sector and not an optimization one. The solution algorithm is based on the minimisation of differences between energy consumption as reported in the national energy balance account and the estimated (by the model) energy consumption. This is achieved by adjusting appropriately the mileage driven by

each vehicle category and in this COPERT version (5.8), as well as in the previous versions, this is done automatically in the model.

The different vehicle categories population along with the total annual kilometres driven by each category as well as fuel consumption data are presented in ***Figures 3.7-3.10.***

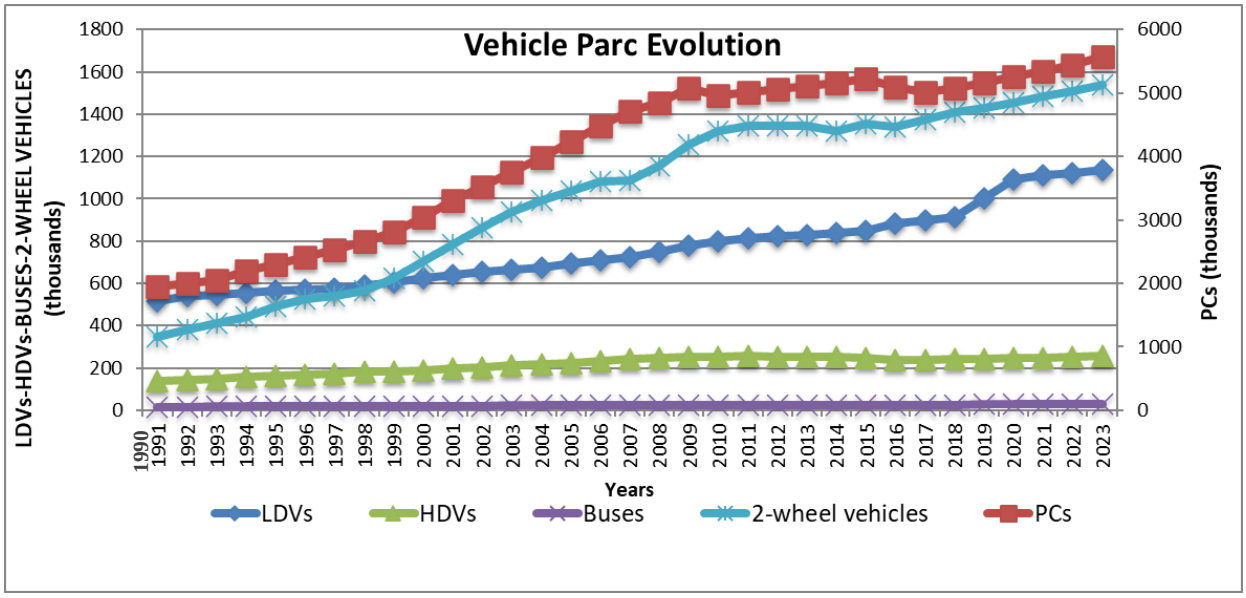


Figure 3.7 ***Vehicles population evolution for all vehicles categories during the whole time period 1990 – 2023***

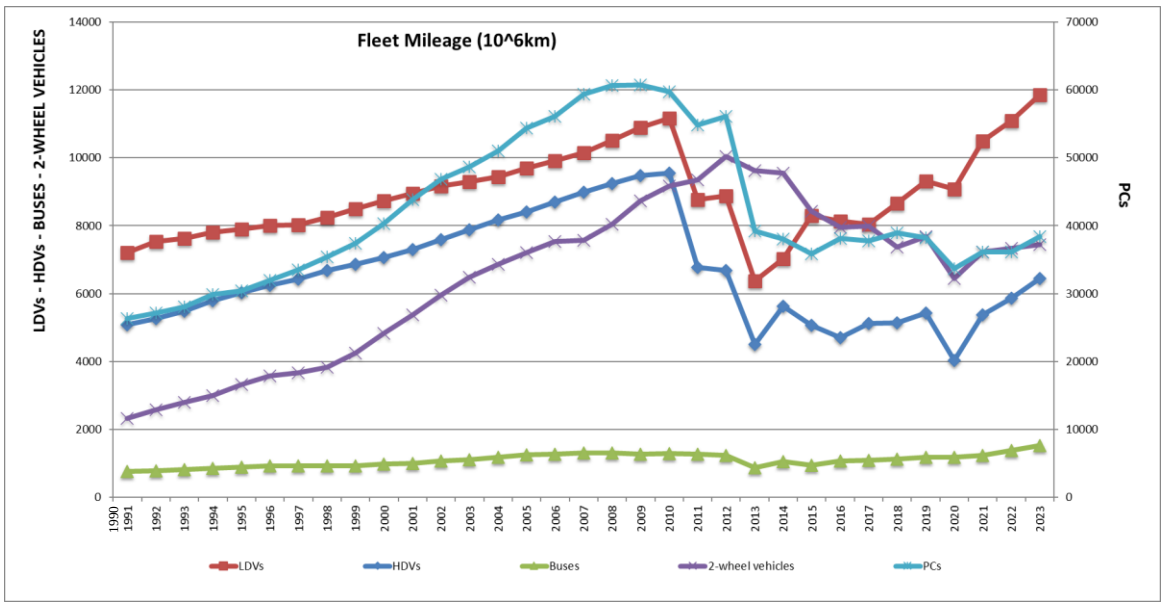


Figure 3.8 ***Annual mileage driven by all vehicles categories during the whole time period 1990 – 2023***

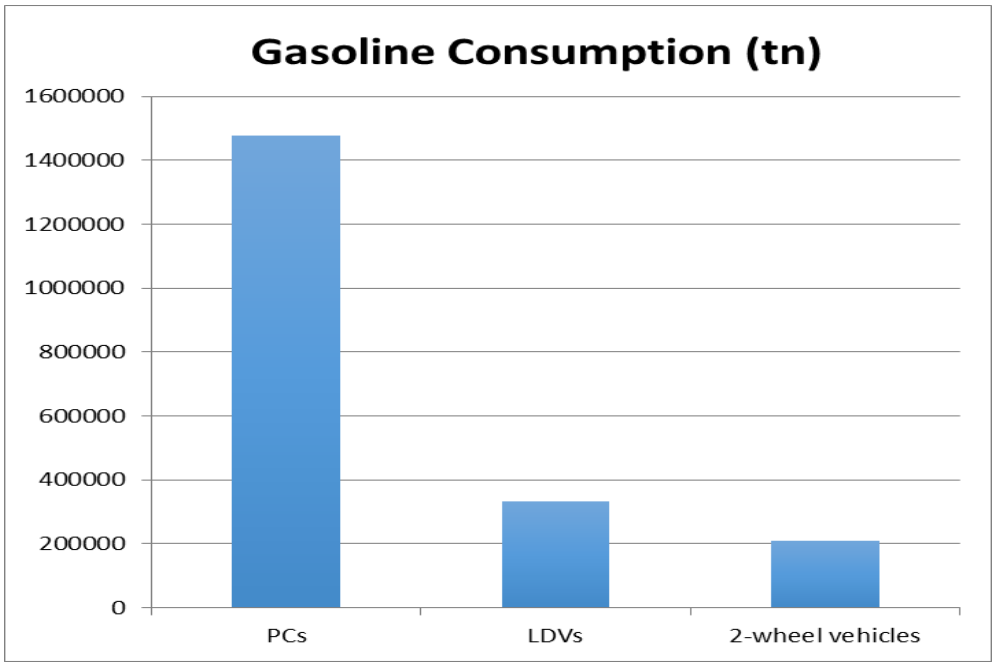


Figure 3.9 Gasoline consumption (kt) by all vehicles categories for 2023

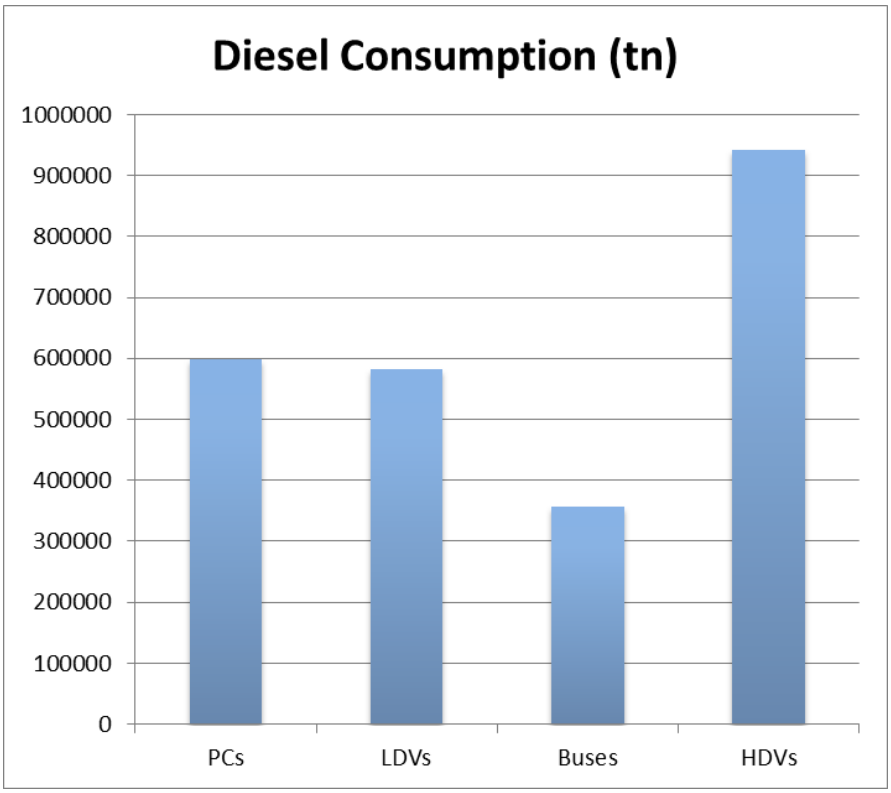


Figure 3.10 Diesel consumption (kt) by all vehicles categories for 2023

Following a recommendation from ERT, the fuel consumption per fuel category for passenger cars has been included in the figure below and the IEFs for CH_4 and N_2O for years 2018-2023, are presented in the following table. Moreover, Greece had already included the trends of vehicle*kms for all vehicle types as these data are being used for the calculation of emissions.

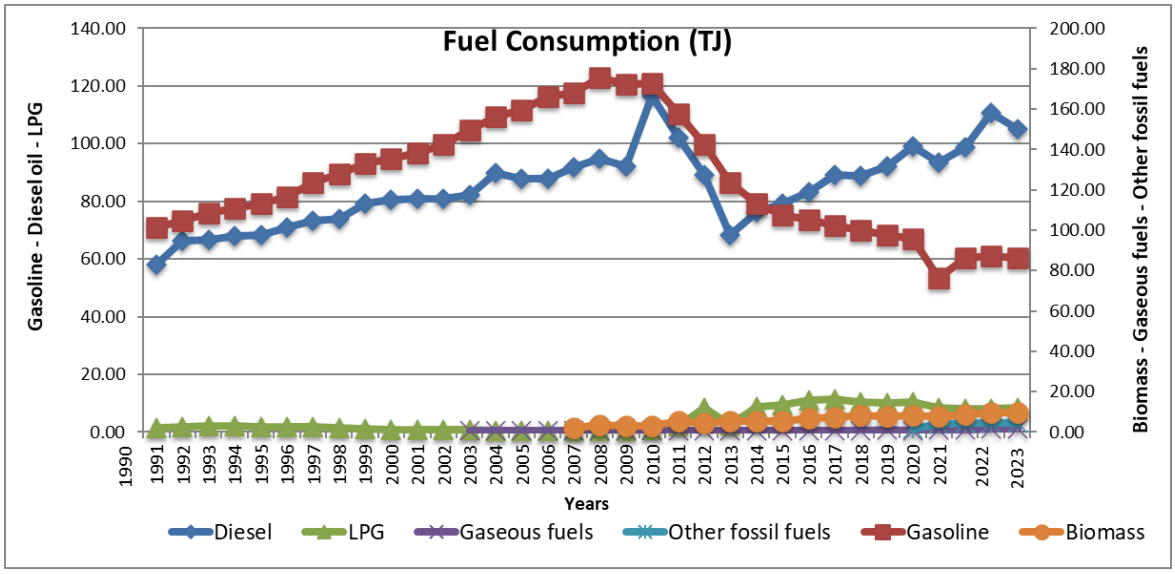


Figure 3.10a Fuel consumption per fuel category during whole time period 1990-2023

Table 3.23 Implied emission factors for CH_4 and N_2O per fuel type

IEFs CH_4 kg/TJ						
Fuel type	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Gasoline	19.99	19.88	19.64	19.57	19.41	18.38
Diesel	4.45	4.01	3.61	3.43	3.27	3.01
Liquefied Petroleum Gases (LPG)	8.67	8.66	8.66	8.55	8.53	8.53
Gaseous fuels	102.22	102.22	102.22	102.22	102.22	102.22
Biomass	4.51	4.95	4.06	3.97	3.59	3.68
IEFs N_2O kg/TJ						
Fuel type	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Gasoline	1.72	1.72	1.65	1.64	1.61	1.56
Diesel	1.99	1.99	1.99	2.00	2.04	2.07
Liquefied Petroleum Gases (LPG)	1.69	1.68	1.68	1.70	1.67	1.64
Gaseous fuels	3.33	3.32	3.33	3.33	3.33	3.33
Biomass	1.99	1.98	1.33	1.37	1.37	1.39

In the last years, the passenger cars fleet has almost tripled compared to 1990 levels, while an increase of the share of medium and larger size passenger vehicles is observed (from 27% in 1990, to 36% in 2008). However, this situation tends to change as a result of the high taxation imposed on vehicles with engines over 2000cm^3 (in 2016, about 28% of passenger cars have an engine capacity greater than 2000cm^3).

In 2015, a sharp increase of diesel passenger cars emissions was observed due to the fact that the old vehicles withdrawal programme was still running in Greece in 2015. As a result, a considerable increase of diesel vehicles, which are mostly preferred by consumers, was recorded and, given that these new vehicles are circulating much more than the older petrol engined vehicles, an increase of fuel consumption and the corresponding emissions was observed. However, this increasing trend of diesel vehicles in the small sector has started to change in 2017, as new technology low consumption gas vehicles have taken an important share in small cars market.

Road transport is a key category of CO_2 emissions. CO_2 emissions in 2023 increased by approximately 25% compared to 1990 emissions, CH_4 emissions decreased (about 49%), while N_2O emissions are at the same level as in 1990 (***Tables 3.24(a,b,c,d))***. During this period, energy consumption augmented by 33%.

Up to 2009, a significant increase of GHG emissions was observed attributed to economic development, an increase in the vehicles fleet as well as in fuel consumption. On the contrary, from 2010, as a consequence of economic crisis, this trend decelerated or inversed, although the percentage of car ownership in Greece is lower than the EU average. It should be noted that, despite the increase of the population of circulating vehicles, as there is a remarkable increase of less polluting vehicles, CO, NOx and NMVOC emissions considerably decrease. Finally, another considerable reduction of SO_2 emissions attributed to the improvement of the fuels' characteristics (i.e. the reduction of their sulphur content) is observed in 2010. In 2020, due to COVID-19 restrictions, a high decrease of emissions in road transport was observed.

Up to 2013 submission, emissions from lubricants combustion in road transportation were estimated using an adjustment coefficient applied to the total lubricants consumption. CO_2 emissions from energy combustion of lubricants from road transportation in 1990 are several times higher than the possible calculations based on fleet data and distance travelled. During the in-country review of initial report (Report FCCC/IRR/2007/GRC / 28Dec2007), the ERT identified this issue as a potential overestimation in the base year and decided to calculate and apply an adjustment for the whole time-series. The ERT concluded that the most appropriate methodology for the adjustment in accordance with the Technical Guidance for Adjustments (attached to decision 20/CMP.1) would be the use of an appropriate driver (lubricant consumption/fuel consumption) from a cluster of countries which estimate CO_2 emissions from the combustion of lubricants. The lubricant consumption per fuel consumption ratio in 1990, based on Greece's activity data allocation, was 0.0236 (3.938,62 TJ/166.745,16 TJ), which was nine times higher than the average of other countries that report CO_2 emissions from combustion of lubricants. To resolve this issue, the ERT and the Greek inventory team compiled a proxy bottom-up calculation for the amount of lubricants combusted in road transportation. This resulted in CO_2 emission estimates an

order of magnitude lower than reported by Greece, comparable with estimates from other Parties. The adjusted estimate for CO_2 emissions from energy combustion of lubricants from road transportation in the base year amounts to 31.71 Gg CO_2 compared to the 142.97 Gg CO_2 originally reported by Greece in the 2006 inventory submission. The respective emissions for 2010 amounts to 51.86 Gg CO_2. For this year's calculations however, the lubricants consumption taken from the energy balance was considered as reliable, as the corresponding lubricant consumption per fuel consumption ratio is 0.0035, hence in the range of accepted values (as reported before). Therefore, the calculations were performed using the statistical lubricants consumption. Similarly, for years 2011 and 2012, the lubricants consumption was taken from the energy balance. It is to be noted that, in 2012, the lubricants consumption considerably decreased as a result of crisis and, possibly, reduced maintenance of vehicles fleet. From 2013, lubricants were calculated according to the new guidelines. Following the revised guidelines, such emissions should be reported separately for (i) 2-stroke engines and (ii) all other engines. As the former work with a gasoline-lubricant mix with the lube oil considered to be a part of the fuel itself, emissions should be reported as part of the CRTs the 2-stroke mobile sources are allocated in (i.e. CRT 1.A.2.g vii, 1.A.3.b, 1.A.4.a ii, b ii, c ii, and c iii). On the other hand, any other emissions from (unintended) lubricant co- combustion should be reported under CRT 2.D.1 – Lubricant use.

CO_2 emissions are based on statistical fuel consumption, therefore all fuel sold is accounted for in the CRT in line with the 2006 IPCC Guidelines. Contrary to CO_2, all the other pollutants emissions are calculated with COPERT and are based on the distance travelled and not on the statistical fuel consumption, as emission factors are determined experimentally with measurements of the gas mass exhausted per kilometre at the end-of-pipe.

It is a fact that we take into account all fuel sold and we compare calculated fuel consumption to the corresponding statistical fuel consumption. However, in the previous years calculations, the fuel consumption cross check could not result in very small differences as statistical fuel consumption data were influenced from illegal activities in the fuel market (e.g. the use of the cheaper heating diesel for vehicles). This is why, in general there was a very good agreement between statistical and calculated gas consumption data, whereas for diesel we had an overestimation with COPERT, as a result of the above-mentioned illegal uses. However, as was already mentioned in previous years NIR, the problem with emissions calculation cross-check using statistical data for energy consumption due to fuel smuggling and other illegal uses, was tackled by Greek government with specific legal measures. Hence, for 2014 and on, we consider that such a comparison is possible and we have performed the cross-check. This is further reflected to the good comparison of calculated versus statistically given fuel consumptions.

Concerning N_2O emissions, it should be noted that N_2O depends on the car fleet composition and characteristics and increases considerably for 1st and 2nd generation catalytic cars, compared to conventional ones, whereas it decreases for newer catalyst equipped cars compared to the older catalytic cars. A second important parameter is the S fuel content that influences considerably the N_2O emissions (2000, 2005 and 2009). All the above parameters contribute to the final formation of the implied emission factors. CH_4 emissions depend also on the car fleet composition and characteristics. As for the fluctuations of the IEF of N_2O and CH_4, they are due to the fact that N_2O and CH_4 are calculated with COPERT based on the fleet composition etc. In general, although statistical fuel consumption is used to calibrate the corresponding calculated consumption, during

the previous years the statistical consumption was smaller than the calculated through COPERT, and, hence the IEF was larger. This difference was discussed in previous NIR submissions and was connected to fuel smuggling and other illegal uses. In 2010, the statistical consumption, as a result of the measures taken along with the economic crisis, has substantially decreased as well as the corresponding calculated fuel consumption and converged with the statistical values and hence, N_2O and CH_4 IEF decreased. Especially for N_2O, an important decrease of the IEF was already observed for year 2009 as a result of the fuel S content decrease. Last but not least, we would like to underline that the old vehicles withdrawal programme that was running in Greece from 2011 has stopped in the end of 2016.

Table 3.24(a) GHG emissions, air pollutants emissions and energy consumption from road transportation for the period 1990 – 1999

Road Transportation	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fuel Consumption	TJ	161185	172677	176893	181013	183515	189417	198512	203096	213313	217089
Emissions											
CO_2	Kt	11793.06	12631.88	12938.22	13238.69	13424.13	13856.47	14524.38	14863.72	15612.53	15892.14
CH_4	Kt	4.28	4.33	4.27	4.34	4.31	4.37	4.40	4.45	4.54	4.67
N_2O	Kt	0.39	0.44	0.51	0.61	0.71	0.81	0.86	0.94	1.03	1.15
NOx	Kt	144.27	146.27	146.74	150.44	151.84	144.56	146.10	148.31	149.66	151.30
CO	Kt	871.84	843.05	793.86	799.44	781.37	694.68	688.72	684.75	684.24	681.23
NMVOC	Kt	137.31	135.73	130.96	131.79	129.69	119.01	118.52	118.22	118.04	117.66
SO_2	Kt	18.74	19.33	20.04	21.00	21.74	11.22	11.56	12.02	12.43	12.96

Table 3.24(b) GHG emissions, air pollutants emissions and energy consumption from road transportation for the period 2000 – 2009

Road Transportation	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fuel Consumption	TJ	219719	224516	232873	246972	248551	255229	263029	275228	268569	294267
Emissions											
CO_2	Kt	16087.03	16437.98	17043.38	18076.63	18193.26	18681.69	19109.11	19881.39	19445.44	21295.88
CH_4	Kt	4.80	4.89	4.84	4.80	4.82	4.73	4.63	4.42	4.16	3.86
N_2O	Kt	0.75	0.78	0.80	0.81	0.84	0.83	0.88	0.89	0.88	0.76
NOx	kt	151.23	153.12	151.68	151.42	152.06	147.14	148.83	146.97	141.97	136.46
CO	kt	634.69	630.91	592.47	571.38	558.38	493.11	510.42	446.87	397.91	375.14
NMVOC	kt	105.34	103.59	97.30	92.24	88.05	77.52	74.91	68.27	60.00	57.35
SO_2	kt	2.77	2.90	2.99	3.10	3.21	0.70	0.72	0.74	0.75	0.76

Table 3.24 (c) GHG emissions, air pollutants emissions and energy consumption from road transportation for the period 2010 – 2019

Road Transportation	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fuel Consumption	TJ	267725	245205	200101	203845	202471	207032	210621	208271	208310	215153.4
Emissions											
CO_2	kt	19187.88	17545.19	14231.96	14457.98	14317.55	14555.69	14787.9	14533.96	14592.54	15010.61
CH_4	kt	4.15	3.65	2.73	3.10	2.93	2.81	2.78	2.58	2.56	2.51
N_2O	kt	0.65	0.45	0.37	0.35	0.35	0.36	0.39	0.39	0.39	0.40
NOx	kt	103.68	85.45	68.10	80.12	76.17	68.49	68.45	72.42	72.03	74.47
CO	kt	317.90	286.93	256.39	240.76	262.79	230.65	197.94	199.45	189.11	185.98
NMVOC	kt	45.63	39.59	35.28	41.15	42.03	38.50	34.94	31.98	30.13	29.76
SO_2	kt	0.13	0.11	0.09	0.09	0.09	0.09	0.09	0.06	0.06	0.060

Table 3.24 (d) GHG emissions, air pollutants emissions and energy consumption from road transportation for the period 2020 - 2023

Road Transportation	Unit	2020	2021	2022	2023
Fuel Consumption	TJ	189712.76	205937.89	219844.69	213990.24
Emissions					
CO_2	kt	13136.46	14263.55	15213.16	14754.41
CH_4	kt	2.07	2.29	2.34	2.19
N_2O	kt	0.34	0.37	0.40	0.39
NOx	kt	67.32	65.55	70.30	65.76
CO	kt	168.13	161.08	160.52	154.57
NMVOC	kt	26.90	25.52	25.53	24.75
SO_2	kt	0.06	0.09	0.09	0.09

Navigation

Carbon dioxide emissions from internal navigation are calculated according to the IPCC Tier 1 default methodology, which is based on the relative consumption of energy per fuel and default emission factors. In Greece, the AD (fuel consumption by fuel type) for navigation, separated between National and International navigation, are obtained from the national energy balance, which is submitted to the EUROSTAT and other international statistics agencies. Hence, these data are verified and accepted as reliable. The consumption fluctuations are affected by the existing national economic conditions and international circumstances, the complication of which overpasses the scope of the present NIR.

The other GHG emissions are calculated according to the default methodology of CORINAIR, which is based on the relative consumption of energy per fuel and default emission factors (SNAP 0804 – EEA 2001). Calculation estimates for emissions from liquid fuels in navigation are based on EFs from the 2006 IPCC Guidelines. EF for N2O for GDO is from Table 1.49 from the Revised 1996 IPCC Guidelines as for this fuel the 2006 IPCC Guidelines do not provide any emission factor.

The application of a higher Tier methodology requires detailed data for the composition of the fleet and the routes performed, which are not available at present. Hence, although in the GPG it is mentioned that "Fuel use data may be obtained using several approaches" and "it may be necessary to combine these data sources to get full coverage of shipping activities", such an approach would promote significant errors due to unreliable data input. On the contrary, the AD (fuel consumption by fuel type) for navigation, separated between National and International navigation, are obtained from the national energy balance, which is submitted to the EUROSTAT and other international statistics agencies and is considered reliable. The different activity data sources mentioned in page 2.54 of the GPG are either unavailable or, even if they are scarcely available, they cannot be combined with the total fuel consumption and lead to consistent calculations.

After a research made with the Laboratory of Fuels of the National Technical University of Athens, new country specific carbon content was applied. As a consequence, recalculations of the whole time series were carried out as country specific EF for CO2 and NCV were used.

Internal navigation (CO_2 emissions) is a key category. GHG emissions from navigation in 2023 were higher by about 14% than the corresponding emissions in 1990, on the basis of fuel consumption data from this sector (***Tables 3.25a,b,c,d***).

It should be noted that recalculations were performed for 2022 emissions, as the biomass fraction was not subtracted from the total gas/diesel oil. Specifically, for 2022 we have recalculated emissions from non biomass fuel, as in last year calculations we calculated these emissions considering total fuel (biomass included).

Table 3.25(a) GHG emissions, air pollutants emissions and energy consumption from domestic navigation for the period 1990 – 1999

Navigation	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fuel Consumption	TJ	23330	23952	24545	22460	23640	22477	19251	23352	36070	35606
Emissions											
CO_2	kt	1808.71	1856.25	1903.32	1739.70	1833.71	1744.94	1495.42	1816.54	2806.60	2774.11
CH_4	kt	0.12	0.12	0.13	0.11	0.13	0.12	0.11	0.13	0.21	0.21
N_2O	kt	0.43	0.46	0.45	0.45	0.42	0.37	0.30	0.32	0.48	0.40
NOx	kt	32.66	33.52	34.37	31.41	33.12	31.52	27.02	32.83	50.73	50.16
CO	kt	4.24	4.35	4.46	4.08	4.30	4.09	3.51	4.26	6.59	6.51
NMVOC	kt	1.38	1.41	1.45	1.32	1.39	1.33	1.14	1.38	2.14	2.11
SO_2	kt	18.61	18.31	19.94	16.17	19.87	19.90	18.07	24.74	39.07	42.53

Table 3.25(b) GHG emissions, air pollutants emissions and energy consumption from domestic navigation for the period 2000 – 2009

Navigation	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fuel Consumption	TJ	20288	27633	24929	24660	27717	26573	29131	27207	24427	36765
Emissions											
CO_2	kt	1574.65	2145.59	1934.50	1915.15	2154.44	2063.50	2262.25	2113.72	1896.39	2864.93
CH_4	kt	0.11	0.15	0.13	0.14	0.16	0.15	0.16	0.15	0.13	0.22
N_2O	kt	0.34	0.45	0.43	0.40	0.41	0.43	0.47	0.42	0.40	0.39
NOx	kt	28.44	38.76	34.94	34.60	38.93	37.28	40.87	38.19	34.26	51.53
CO	kt	3.69	5.03	4.54	4.49	5.05	4.84	5.31	4.96	4.45	6.69
NMVOC	kt	1.20	1.63	1.47	1.46	1.64	1.57	1.72	1.61	1.44	2.17
SO_2	kt	17.57	24.83	21.13	22.62	27.48	26.12	28.70	25.78	21.68	45.20

Table 3.25(c) GHG emissions, air pollutants emissions and energy consumption from domestic navigation for the period 2010 – 2019

Navigation	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fuel Consumption	TJ	29961	21479	21533	17929	18736	22299	23166	23717	25731	26613
Emissions											
CO_2	kt	2331.43	1667.44	1676.33	1394.25	1456.86	1734.15	1800.63	1843.53	2000.12	2068.06
CH_4	kt	0.18	0.12	0.13	0.10	0.11	0.13	0.13	0.13	0.14	0.15
N_2O	kt	0.37	0.34	0.26	0.24	0.25	0.30	0.33	0.34	0.36	0.39
NOx	kt	41.78	41.95	30.15	34.67	36.17	43.05	44.77	45.86	46.36	51.44
CO	kt	5.42	5.45	3.91	3.25	3.39	4.03	4.20	4.30	4.95	4.82
NMVOC	kt	1.76	1.77	1.27	1.20	1.26	1.49	1.56	1.59	1.72	1.79
SO_2	kt	10.58	10.62	7.64	8.78	9.16	10.90	11.34	11.62	12.53	13.03

Table 3.25(d) GHG emissions, air pollutants emissions and energy consumption from domestic navigation for the period 2020 – 2023

Navigation	Unit	2020	2021	2022	2023
Fuel Consumption	TJ	21470.84	23639.54	25685.77	26555.11
Emissions					
CO_2	kt	1668.16	1835.07	1993.37	2060.29
CH_4	kt	0.12	0.13	0.14	0.15
N_2O	kt	0.29	0.35	0.40	0.42
NOx	kt	41.4	45.27	49.51	49.89
CO	kt	3.88	4.27	4.64	4.68
NMVOC	kt	1.437	1.58	1.72	1.74
SO_2	kt	10.48	11.54	12.55	12.64

Domestic aviation

Since 2005, GHG emissions from domestic aviation were taken from EUROCONTROL, based on the combination of energy consumption data and air traffic data (Landing and Take off cycles, LTOs) as well as from aircraft fleet composition. EUROCONTROL calculations use Tier 3 approach to assess air pollutants from air traffic. For consistency reasons, the whole series from 1990 to 2004 was recalculated. For domestic and International Aviation, fuel burnt are taken directly from Eurocontrol data (Tier 3 method).

In order to follow IPCC Good Practice, we consider that all fuel that appears in the national energy balance should be included in the inventory. Thus, aviation jet kerosene fuel for 1A5 category is taken as the result of the substraction of domestic aviation fuel from Eurocontrol and International fuel from Eurocontrol from total fuel from energy balance. Total fuel from energy balance results from domestic aviation, international aviation and other non specified fuel consumed. By this way all kerosene jet fuel that appears in the energy balance and its associated emissions are included in the inventory. Emissions from aviation gasoline are not changed. CH_4 and N_2O emissions for the whole timeseries are estimated by Tier 1 with D IPCC Efs. These emissions are not a key category, therefore, it is a good practice to apply Tier 1.

The data on energy consumption derive from the national energy balance and EUROCONTROL, while data on LTOs are provided by the Civil Aviation Organization and EUROCONTROL.

Although in 2009, GHG emissions from internal aviation have almost doubled, compared to 1990 emissions, in 2023, the corresponding increase is 24% (***Table 3.26(a,b.c,d)***).

It is to be noted that the high decrease in 2020 compared to 2019 is totally attributed to the COVID-19 restrictions in transport sector.

Road transportation data include emissions from ground activities in airports and thus, all emissions are reported. The problem is that there are no detailed data in order to calculate separately these emissions and thus having the possibility to reallocate them.

Table 3.26(a) GHG emissions, air pollutants emissions and energy consumption from domestic aviation for the period 1990 – 1999

Domestic Aviation	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fuel Consumption	TJ	4534.90	3966.86	4364.79	4801.04	4810.86	5100.73	5472.70	6218.04	6324.48	7562.43
Emissions											
CO_2	kt	323.42	282.85	311.22	342.33	343.01	363.68	390.20	443.34	450.93	539.20
CH_4	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
NOx	kt	1.12	0.98	1.07	1.18	1.18	1.25	1.35	1.53	1.56	1.86
CO	kt	0.81	0.71	0.78	0.86	0.86	0.91	0.97	1.11	1.12	1.34
NMVOC	kt	0.19	0.16	0.18	0.20	0.20	0.21	0.23	0.26	0.26	0.31
SO_2	kt	0.09	0.08	0.09	0.10	0.10	0.11	0.11	0.13	0.13	0.16

Table 3.26(b) GHG emissions, air pollutants emissions and energy consumption from domestic aviation for the period 2000 – 2009

Domestic Aviation	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fuel Consumption	TJ	8403.55	7530.50	6469.90	7389.75	8535.78	6994.04	7737.35	7935.27	7169.96	8052.65
Emissions											
CO_2	kt	599.18	536.91	461.29	526.89	607.16	497.84	550.50	564.90	510.23	573.08
CH_4	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O	kt	0.02	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.02
NOx	kt	2.07	1.85	1.59	1.82	1.97	1.66	1.84	1.88	1.70	1.91
CO	kt	1.50	1.34	1.15	1.31	1.42	1.28	1.42	1.46	1.32	1.48
NMVOC	kt	0.35	0.31	0.27	0.31	0.33	0.30	0.33	0.34	0.31	0.35
SO_2	kt	0.17	0.16	0.13	0.15	0.17	0.15	0.17	0.17	0.15	0.17

Table 3.26 (c) GHG emissions, air pollutants emissions and energy consumption from domestic aviation for the period 2010 – 2019

Domestic Aviation	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fuel Consumption	TJ	6591.71	7293.60	6703.73	4736.81	5064.22	5459.42	5750.35	5656.31	5900.09	5749.77
Emissions											
CO_2	kt	470.12	520.39	478.59	338.08	361.46	389.63	410.48	403.52	421.32	409.97
CH_4	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
N_2O	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NOx	kt	1.56	1.73	1.59	1.12	1.20	1.30	2.04	1.34	1.93	1.85
CO	kt	1.21	1.34	1.23	0.87	0.93	1.00	0.64	1.04	0.64	0.65
NMVOC	kt	0.28	0.31	0.29	0.20	0.22	0.23	0.08	0.24	0.06	0.06
SO_2	kt	0.14	0.16	0.14	0.10	0.11	0.12	0.11	0.12	0.11	0.11

Table 3.26 (d) GHG emissions, air pollutants emissions and energy consumption from domestic aviation for period 2020 - 2023

Domestic Aviation	Unit	2020	2021	2022	2023
Fuel Consumption	TJ	2991.81	4488.02	5454.09	5745.52
Emissions					
CO_2	kt	213.45	320.32	389.39	416.10
CH_4	kt	0.0015	0.002	0.0027	0.0029
N_2O	kt	0.0059	0.0090	0.0109	0.0115
NOx	kt	0.96	1.45	1.81	1.89
CO	kt	0.32	0.56	0.69	0.72
NMVOC	kt	0.03	0.04	0.04	0.04
SO_2	kt	0.06	0.08	0.10	0.11

Railways

GHG emissions from railways are calculated according to the IPCC Tier 1 default methodology, which is based on the relative consumption of energy per fuel and default emission factors. The EFs applied are from the 2006 IPCC Guidelines. Specifically, EF for N_2O and CH_4 is from Table 3.4.1 from the IPCC Guidelines. However, for CO_2, the country specific emission factor is used as already explained in paragraph 3.2.5.2 (Road Transport).

In Greece, the fuel consumption (by fuel type) for railways, is obtained from the national energy balance, which is submitted to EUROSTAT and other international statistics agencies. Hence, these data are verified and accepted as reliable.

GHG emissions from railways for the period 1990-2023 are presented in the Tables below (***Tables 3.27(a,b,c,d)***).

Table 3.27(a) GHG emissions, air pollutants emissions and energy consumption from railways for the period 1990 – 1999

Railways	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Fuel Consumption	TJ	2717	2113	2027	2070	2242	1854	1940	1811	2027	1765
Gas/ Diesel oil		2717	2113	2027	2070	2242	1854	1940	1811	2027	1765
Biodiesel		-	-	-	-	-	-	-	-	-	-
Emissions											
CO_2	kt	198.94	154.73	148.42	151.58	164.21	135.79	142.10	132.63	148.42	129.24
CH_4	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	kt	0.08	0.06	0.06	0.06	0.06	0.05	0.06	0.05	0.06	0.05
NOx	kt	2.49	1.94	1.86	1.90	2.06	1.70	1.78	1.66	1.86	1.58
CO	kt	0.67	0.52	0.50	0.51	0.56	0.46	0.48	0.45	0.50	0.43
NMVOC	kt	0.29	0.23	0.22	0.22	0.24	0.20	0.21	0.20	0.22	0.19
SO_2	kt	1.26	0.98	0.94	0.96	1.04	0.86	0.90	0.84	0.94	0.80

Table 3.27(b) GHG emissions, air pollutants emissions and energy consumption from railways for the period 2000 – 2009

Railways	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Fuel Consumption	TJ	1765	1765	1765	1765	1765	1750	1793	1622	1579	1322
Gas/ Diesel oil		1765	1765	1765	1765	1765	1750	1793	1622	1579	1322
Biodiesel		-	-	-	-	-	-	-	-	-	-
Emissions											
CO_2	kt	129.24	129.24	129.24	129.24	129.24	128.15	131.28	118.76	115.63	96.85
CH_4	kt	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	kt	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
NOx	kt	1.58	1.58	1.58	1.58	1.58	1.58	1.62	1.47	1.43	1.19
CO	kt	0.43	0.43	0.43	0.43	0.43	0.43	0.44	0.40	0.39	0.32
NMVOC	kt	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.17	0.17	0.14
SO_2	kt	0.80	0.80	0.80	0.80	0.80	0.80	0.82	0.74	0.72	0.60

Table 3.27(c) GHG emissions, air pollutants emissions and energy consumption from railways for the period 2010 – 2019

Railways	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fuel Consumption	TJ	855	641	1069	770	1838	1838	1796	1749.9	1660.9	446
Gas/ Diesel oil		855	641	1069	770	1838	1710	1710	1668.4	1584.7	446
Biodiesel		-	-	-	-	-	128.3	85.5	81.6	76	-
Emissions											
CO_2	kt	62.61	46.96	78.27	56.35	134.62	125.22	125.22	122.17	116.05	32.62
CH_4	kt	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00
N_2O	kt	0.02	0.02	0.03	0.02	0.05	0.05	0.05	0.05	0.05	0.01
NOx	kt	0.79	0.59	0.99	0.71	1.70	1.70	1.66	1.62	1.53	0.41
CO	kt	0.21	0.16	0.27	0.19	0.46	0.46	0.45	0.44	0.42	0.11
NMVOC	kt	0.09	0.07	0.12	0.08	0.20	0.20	0.20	0.19	0.18	0.05
SO_2	kt	0.40	0.30	0.50	0.36	0.09	0.09	0.08	0.08	0.08	0.02

Table 3.27(d) GHG emissions, air pollutants emissions and energy consumption from railways for the period 2020 - 2023

Railways	Unit	2020	2021	2022	2023
Fuel Consumption	TJ	311.48	281.85	292.20	175.62
Gas/ Diesel oil		311.48	281.85	292.20	175.62
Biodiesel		-	-	-	
Emissions					
CO_2	kt	22.81	20.64	21.40	12.86
CH_4	kt	0.00	0.00	0.00	0.00
N_2O	kt	0.01	0.01	0.01	0.01
NOx	kt	0.29	0.26	0.27	0.16
CO	kt	0.08	0.07	0.07	0.04
NMVOC	kt	0.03	0.03	0.03	0.02
SO_2	kt	0.01	0.01	0.01	0.01

Following a recommendation from ERT, in the Table below it is presented the Implied Emission factors for N_2O and CH_4 used by type of fuel.

Table 3.28 (a) Implied emission factors by type of fuel for the period 1990-1999

Railways	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
IEF Gas/ Diesel Oil											
CH_4	kg/TJ	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
N_2O	kg/TJ	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60
IEF Biodiesel											
CH_4	kg/TJ	-	-	-	-	-	-	-	-	-	-
N_2O	kg/TJ	-	-	-	-	-	-	-	-	-	-

Table 3.28 (b) Implied emission factors by type of fuel for the period 2000-2009

Railways	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
IEF Gas/ Diesel Oil											
CH_4	kg/TJ	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
N_2O	kg/TJ	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60
IEF Biodiesel											
CH_4	kg/TJ	-	-	-	-	-	-	-	-	-	-
N_2O	kg/TJ	-	-	-	-	-	-	-	-	-	-

Table 3.28 (c) Implied emission factors by type of fuel for the period 2000-2020

Railways	Unit	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IEF Gas/ Diesel Oil												
CH_4	kg/TJ	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
N_2O	kg/TJ	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60	28.60
IEF Biodiesel												
CH_4	kg/TJ	-	-	-	-	-	4.15	4.15	4.15	4.15	-	-
N_2O	kg/TJ	-	-	-	-	-	28.60	28.60	28.60	28.60	-	-

Table 3.28 (d) Implied emission factors by type of fuel for the period 2021-2023

Railways	Unit	2021	2022	2023
IEF Gas/ Diesel Oil				
CH_4	kg/TJ	4.15	4.15	4.15
N_2O	kg/TJ	28.60	28.60	28.47
IEF Biodiesel				
CH_4	kg/TJ	-	-	
N_2O	kg/TJ	-	-	

3.2.5.3 Uncertainties and time-series consistency

Road Transport

Several input data in applying the methodology can obviously be only estimates. Such data include total annual mileage, share of mileage to different driving modes (urban, rural, highway), mean travelling speeds, etc. There is a certain degree of uncertainty in estimating these data. A firm checkpoint in estimating the accuracy of calculations is that the total calculated fuel consumption per fuel type should equal the consumption statistics for the level of activity considered.

In principle systematic errors may be distinguished into two categories:

- Errors concerning emission factors and measurements (e.g. driving cycles applied)
- Errors concerning assessment of vehicle park and usage (e.g. errors in total kilometres travelled and in the average trip length as well as erroneous estimates of the vehicle park sub-categories.

Aviation

In this sector an important uncertainty parameter is the assessment of aircraft types. In our case the lack of relevant data does not allow the application of a higher Tier methodology and, hence, the emission factors used only partially reflect the aircraft fleet. However, EUROCONTROL has performed detailed, Tier 3, calculations from 2005 which were taken into account. For consistency, emissions from 1990-2004 were also recalculated.

Navigation

In the navigation sector uncertainty is mostly connected to the general lack of data concerning the type of the engines of the ships as well as their use (fuel consumption for vessel categories) and ship movement information.

3.2.5.4 Source-specific QA/QC and verification

Road traffic

1. Cross-checking vehicles fleet comparing to the previous year data
2. Cross-checking fuel consumption data from the energy balance with the respective data calculated from COPERT.

3. Association of emissions trends with the input parameters trends.

Aviation

1. Cross-checking consumption data and number of flights
2. Cross-checking data trends and emissions trends

Railways/Navigation

1. Cross-checking data trends and emissions trends

3.2.5.5 Recalculations

Navigation

We have recalculated 2022 emissions, as we had not subtracted the biomass fraction from total gas/diesel oil. Specifically, for 2022 we have recalculated emissions from non biomass fuel as in last year calculations we calculated these emissions considering total fuel (biomass included).

3.2.5.6 Planned improvements

Future actions for the improvement of the estimation of GHG emissions from transport include the following:

Road Transport

- The reconstruction of the whole timeseries fleet population and composition database is already being accomplished based on the most up to date and accurate data existed. However, the effort still continues for further improvement in the future.
- As was already mentioned in previous years NIRs, the problem with emissions calculation cross-check using statistical data for energy consumption due to fuel smuggling and other illegal uses, was tackled by Greek government with specific legal measures. However, still new measures are planned to be taken to further limit fuel smuggling and illegal uses.

Navigation

- In the navigation sector, there is a very limited possibility to use detailed fleet data in order to calculate emissions. The application of the analytic methodology requires detailed data for the composition of the fleet and the routes performed, which are not available at present.

3.3 Fugitive emissions from fuels (CRT Source Category 1.B)

3.3.1 Coal mining and handling (CRT Source Category 1.B.1a)

3.3.1.1 Source category description

The geological process of coal formation also produces methane (CH_4), some of which remains trapped in the coal seam until it is mined. Generally, deeper underground coal seams contain more in-situ methane than shallower, surface seams.

Coal mining in Greece concerns exclusively the extraction of lignite. All lignite mines in Greece are surface mines and methane is emitted directly into the atmosphere, as the rock strata overlying the coal are removed during the process.

Fugitive emissions from coal mining and handling (CH_4 emissions) are a trend key category. CH_4 emissions (***Table 3.29***) from the mining of lignite in 2023 account for 0.37% of total GHG emissions. A 79.2% decrease for the period 1990 – 2023 is observed. This decrease is attributed to the gradual phasing-out of lignite-fired power plants in recent years. According to the NECP of Greece, there is an undergoing plan for the phasing-out of all but one lignite-plants till the mid of the current century. The remaining plant will be converted to NG by 2028.

Table 3.29 ***CH_4 emissions from lignite mining (in kt) and primary production of lignite (in Mt) for the period 1990 – 2023***

Year	Production (Mt)	CH_4 emissions (kt)
1990	51.90	45.20
1991	52.70	45.90
1992	55.05	47.95
1993	54.82	47.75
1994	56.67	49.36
1995	57.66	50.22
1996	59.78	52.07
1997	58.84	51.25
1998	60.88	53.03
1999	62.05	54.05
2000	63.89	55.65
2001	66.34	57.79
2002	70.47	61.38
2003	68.30	59.49
2004	70.04	61.01
2005	69.40	60.45
2006	64.52	56.20
2007	66.46	57.89
2008	65.72	57.24
2009	64.89	56.52
2010	56.52	49.23
2011	58.67	51.10
2012	62.96	54.83
2013	53.92	46.97
2014	50.85	44.29
2015	46.25	40.28
2016	32.64	28.43
2017	37.73	32.86
2018	36.49	31.78
2019	27.38	23.84
2020	14.05	12.24
2021	12.40	10.80
2022	14.25	12.41
2023	10.77	9.38

3.3.1.2 Methodological issues

CH_4 emissions from lignite mining are calculated on the basis of lignite production and the use of typical emission factor (Tier 1 methodology), as information with regard to the availability of measurements that would allow the calculation of national factors do not exist. More specifically:

- The national energy balance is the basic source for the activity data (production of lignite, see Table 3.29) used for the calculation of emissions.
- The typical emission factors (1.2 m^3 / t of lignite plus 0.1 m^3 / t of lignite for surfacing mining and post-mining activities, respectively) suggested by 2006 IPCC GLs is used. The density of methane has been considered equal to 0.67 kg / m^3.

3.3.1.3 Recalculations

No recalculation was performed in 2025 submission, but are under consideration for the next submissions as it is described in the next section.

3.3.1.4 Source-specific QA/QC and verification and planned improvements

According to GPG, when surface mining is a key category, it is good practice to estimate emissions using national emission factors. The inventory team has contacted the Public Power Company (PPC), which is the operator of all lignite mines in Greece, in order to gather information (site measurements) for the estimation of a national EF. However, the inventory team was informed that the needed measurements are not available, since they are very difficult and expensive to carry out and that the PPC lacks the necessary know-how to contact such measurements.

Moreover, for verification purposes, the inventory team examined the NIR and CRT tables of other Parties, which report CH4 emissions from surface mining of lignite by using a Tier 2 approach (national Efs). Three parties were identified, namely Germany, Poland and Spain. The implied Efs they use in 2010 submission were 0.011, 0.01 and 0.31 kg CH4 /t lignite produced (mining and post mining activities included), respectively. The respective EF of Greece is 0.87 kgCH4/t lignite produced (=1.2m^3 CH4/t lignite * 0.67 kgCH4 / m^3CH4), which is by one or two orders of magnitude higher. Therefore, comparing the CH4 emissions from surface mining reported by Greece with the ones reported by other KP parties, it is concluded that the reported CH4 emissions by Greece are rather conservative and for sure they are not underestimated.

The inventory team has contacted the inventory teams of some countries that apply a CS EF for CH4 emissions associated to surface lignite mining. However, the countries that were approached have developed a CS EF for surface mining based on measurements from underground mines, which are located in the vicinity of the surface mines. Since in Greece, there are no underground mines in the vicinity of surface mines, this method cannot be applied.

The inventory team has initiated an analysis of the possibility of updating the EF, by focusing to the age of the coal layer (very old in Greece) and its depth (very close to the surface) and correlate with the CH4 content of the lignite layer. Results of this analysis will be provided in the next NIRs.

The release of methane from lignite deposits is determined by several factors, the most crucial being pressure, depth, temperature, carbonation level, and petrographic composition. In the case of Greek deposits exploited by PPC:

- The deposits, located in Ptolemaida, Florina, and Megalopolis, are relatively young, formed between the Eocene and lower Pleistocene.
- The lignite is extracted from open-air mining, resulting in lower methane emissions compared to underground mining.
- These deposits are shallow because of their youth.
- The level of carbonization is lower compared to deposits in other European countries. Carbonization refers to the process of enriching carbon (C) in plant matter due to a lack of oxygen and low pH value. As young deposits, these have spent less time under pressure and heat, resulting in slower carbonation progress.

Therefore, from the above, it follows that the deposits of Greece have a lower methane concentration compared to deposits of other EU countries as described in the above paragraphs.

The Emission Factor for Greek lignite is likely to be lower than that of other EU countries where lignite mining is carried out in older deposits, such as Germany and Poland. This is because all lignite mining in Greece takes place in open-air mines, which have lower methane emissions.

Until the completion of the ongoing measurement of the methane Emission Factor for Greek lignite mines, the inventory team is of the view that using a factor of 0.01 kg CH4/t of produced lignite is considered a conservative approach. In reality, the factor is expected to be lower. Therefore, from 2025 submission and onwards the EF 0.01 kg CH4/t of produced lignite will be applied.

3.3.2 SO2 scrubbing (CRT Source Category 1.B.1c)

3.3.2.1 Source category description

When SO_2 scrubbing technology is used in conjunction with combustion of coal, the process, which removes sulphur dioxide from the flue gas, also releases CO_2 from the chemical reactions during the process. Typically, calcium carbonate reacts with sulphur oxides in flue gas to produce calcium sulphate and carbon dioxide. The emissions of this category have been reallocated to the Industrial Processes sector (2.A.3), as from 2010 submission.

3.3.3 Oil and natural gas (CRT Source Category 1.B.2)

3.3.3.1 Source category description

Activities related to primary production (extraction), processing, storage and transmission/ distribution of crude oil, petroleum products and natural gas are included in this sector. GHG released in the atmosphere during these operations is the direct result of leaks, disruptions and maintenance procedures. Moreover, the sector includes also emissions resulting from venting and flaring of gases that cannot be controlled by other means.

- The Greek market of oil and petroleum products comprises four refineries, approximately 50 companies active in the marketing of petroleum products and a large number of retailers and gas stations. Refinery gross output of oil products was 28.8 Mt in 2020. All four large refineries in Greece are located close to the shore, and therefore have their own harbors and are equipped with deloading installations.
- The basic infrastructure of the system for transport, storage and distribution of natural gas in Greece includes (a) the main pipeline with a length of 512 km, and branch pipelines to several cities with a length of about 953.2 km, (b) the terminal of the liquefied natural gas with a total capacity of 225,000 m^3 and (c) the medium and low pressure distribution network of natural gas. The expected length of the low pressure network, to cover the needs of four major Greek cities (Athens, Thessalonica, Larissa and Volos) is 6,500 km.

GHG emissions (***Table 3.30***) from oil and natural gas in 2023 accounted for 0.24% of total GHG emissions from *Energy*. Overall, emissions in 2022 increased by about 57.5% compared to 1990 levels.

The parameters affecting GHG emissions trends from oil and natural gas are the gradual penetration of natural gas in the Greek energy system and the domestic production of crude oil and natural gas.

- The introduction of natural gas in the Greek energy system started in 1996 and at the moment its development is in progress.
- The domestic production of crude oil and natural gas (***Table 3.31a*** and ***Table 3.31b*** respectively) present a continuous decreasing trend and as a result emissions from venting and flaring are decreasing.

3.3.3.2 Methodological issues

GHG emissions from oil and natural gas are estimated according to the Tier 1 methodology described in the 2006 IPCC GLs.

In relation to the estimation of emissions from oil systems, the following should be noted:

- The national balance of energy is the main source of information regarding the activity data, (see Table 3.31a) used for the calculation of emissions.
- Emissions are estimated for the following activities:
  - Primary production and transport of crude oil (CO_2, CH_4 and NMVOC),
  - Oil transport (CH4)
  - Refining and storage of oil products (CH_4, NOx, CO, NMVOC and SO_2),
  - Distribution of oil products (NMVOC) and
  - LPG transport (CO_2 and N_2O).
- Emissions from LPG transport are reported under Other (1.B.2d – Other).
- CO2, CH4 and N2O emissions from the exploration of oil and CO2 emissions from oil transport were reported as "NE" (not estimated). These emissions are considered insignificant, as defined in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, because of the low level of crude oil production (Tables 3.31a). For example, by applying the tier 1 2006 IPCC methodology, the CO2, CH4 and N2O emissions for 2017 from the exploration of oil will be less than 3 ktCO2eq.

In all cases the emission factors are estimated as the average values of the proposed range from 2006 IPCC GLs.

Table 3.30 ***GHG emissions (in kt CO2 eq) from oil and natural gas for the period 1990 – 2023***

Year	Oil	Natural gas	Venting and flaring
1990	9.74	9.25	60.28
1991	8.74	8.64	61.06
1992	9.02	8.18	51.17
1993	7.52	5.89	41.66
1994	9.29	2.25	36.96
1995	9.79	2.10	32.30
1996	11.80	2.32	35.78
1997	11.93	5.51	33.13
1998	12.02	19.25	25.95
1999	10.27	23.16	7.97
2000	12.58	29.59	28.91
2001	12.31	29.24	22.76
2002	11.90	31.91	23.10
2003	12.31	36.39	20.73
2004	11.99	40.86	21.61
2005	11.95	45.69	20.67
2006	12.12	52.97	22.70
2007	12.30	59.19	24.47
2008	11.51	64.87	23.92
2009	11.00	62.27	22.17
2010	12.45	66.28	25.91
2011	10.60	83.52	28.39
2012	13.14	75.81	26.29
2013	12.75	69.38	22.67
2014	13.26	60.48	18.03
2015	13.90	65.71	18.82
2016	14.93	69.31	31.24
2017	15.44	86.94	32.72
2018	15.68	78.41	36.99
2019	14.82	82.20	36.04
2020	14.27	87.78	33.26
2021	15.18	94.45	33.61
2022	15.76	86.87	28.65
2023	16.76	82.53	27.51

Table 3.31a ***Key activity data for the estimation of GHG emissions from oil systems for the period 1990 – 2023***

Year	Primary production		Imports
	Crude oil (kt)	Natural gas liquids (kt)	Crude oil (kt)
1990	773	57	14539
1991	789	47	12362
1992	653	34	13967
1993	537	25	11777
1994	500	31	12914
1995	435	22	15329
1996	483	31	17529
1997	436	29	17957
1998	293	22	18569
1999	15	1	15944
2000	256	23	19371
2001	171	20	18906
2002	165	24	19116
2003	120	17	19782
2004	118	15	20297
2005	100	11	18699
2006	94	11	19836
2007	74	7	20330
2008	59	3	19286
2009	80	7	17780
2010	115	9	20129
2011	98	8	16514
2012	94	8	20978
2013	70	6	19434
2014	64	5	20826
2015	62	3	22085
2016	176	0	23462
2017	142	0	23667
2018	206	0	24330
2019	169	0	23027
2020	92	0	22241
2021	59	0	23711
2022	30	0	21928
2023	51	0	23379

The decrease in production between 1998 and 1999 (in tables 3.31a and 3.31b) is attributable to the suspension of the operation of the only plant producing oil and natural gas in Greece owing to a gradual decline in domestic oil production, a significant decline in crude oil and gas prices and the withdrawal of a foreign joint-venture partner. Production resumed in 2000 following the reopening of the plant, whose operation was taken over by the Government.

In relation to the estimation of emissions from natural gas systems, the following should be noted:

- Activity data for the estimation of emissions (Table 3.31b) derive from the national energy balance.
- Emissions are estimated for the following activities
  - Production and processing of natural gas (CO_2 and CH_4) and
  - Transmission and distribution of natural gas (CH_4).
- The use of natural gas in the period 1990 – 1995 (domestic natural gas only) is negligible (self-consumption in the energy sector and feedstock for ammonia production) and restricted at the area of production.
- The emission factors used for the estimation CO_2 and CH_4 emissions derive from the 2006 IPCC GLs.
- CO2 and CH4 emissions from the exploration of natural gas were reported as "NE" (not estimated). These emissions are considered insignificant, as defined in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, because of the low level of NG production (Tables 3.31b). For example, by applying the tier 1 2006 IPCC methodology, the CO2 and CH4 emissions for 2017 from the exploration of oil will be less than 3 ktCO2eq.

Table 3.31b Key activity data for the estimation of GHG emissions from natural gas systems for the period 1990 – 2023

Year	Primary production	
	Natural gas (10^6 m^3)	Sour gas (%)
1990	123	29%
1991	116	37%
1992	109	33%
1993	81	33%
1994	38	79%
1995	36	69%
1996	38	68%
1997	37	51%
1998	33	61%
1999	2	50%
2000	36	47%
2001	35	46%
2002	37	73%
2003	27	7%
2004	25	20%
2005	16	25%
2006	23	17%
2007	21	14%
2008	14	21%

2009	11	36%
2010	7	86%
2011	6	67%
2012	6	67%
2013	6	67%
2014	5	60%
2015	4	50%
2016	9	47%
2017	8	92%
2018	12	97%
2019	8.9	94%
2020	6.5	81%
2021	4.0	76%
2022	2.0	89%
2023	2.0	90%

In relation to emissions from venting and flaring (CO_2, CH_4 and N_2O), it should be mentioned that in most cases more than one variable is used as activity data (see ***Table 3.32*** for a detailed presentation of emissions from venting and flaring) and as a result significant inter-annual changes are observed in both emissions and implied emission factors.

3.3.3.3 Recalculations

No recalculation was performed in this submission.

Table 3.32 GHG emissions (in kt) from venting and flaring for the period 1990 – 2023

	Venting	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Oil	CO_2	0.09	0.09	0.07	0.06	0.06	0.05	0.05	0.05	0.03	0.00	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	CH_4	0.65	0.67	0.55	0.45	0.42	0.37	0.41	0.37	0.25	0.01	0.22	0.14	0.14	0.10	0.10	0.08	0.08	0.06	0.05	0.07	0.10
NG	CO_2	4.92	4.64	4.36	3.24	1.52	1.44	1.52	1.48	1.32	0.08	1.45	1.41	1.49	1.09	1.01	0.65	0.93	0.85	0.57	0.45	0.29
	CH_4	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.04	0.16	0.27	0.37	0.37	0.39	0.44	0.49	0.52	0.60	0.73	0.77	0.64	0.70
	Flaring																					
Oil	CO_2	37.14	37.91	31.37	25.80	24.02	20.90	23.21	20.95	14.08	0.72	12.30	8.22	7.93	5.77	5.67	4.80	4.52	3.56	2.83	3.84	5.53
	CH_4	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N.G.	CO_2	0.52	0.49	0.46	0.34	0.16	0.15	0.16	0.16	0.14	0.01	0.15	0.15	0.16	0.11	0.11	0.07	0.10	0.09	0.06	0.05	0.03
	CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	Venting	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Oil	CO_2	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.01
	CH_4	0.08	0.08	0.06	0.05	0.05	0.15	0.12	0.17	0.14	0.08	0.05	0.03	0.04
N.G.	CO_2	0.25	0.25	0.25	0.21	0.17	0.37	0.35	0.48	0.37	0.28	0.18	0.10	0.10
	CH_4	0.85	0.78	0.70	0.53	0.57	0.74	0.90	0.88	0.95	1.06	1.17	0.94	0.85
	Flaring													
Oil	CO_2	4.71	4.52	3.36	3.07	2.98	8.46	6.80	9.92	8.10	4.40	2.82	1.44	2.44
	CH_4	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N.G.	CO_2	0.03	0.03	0.03	0.02	0.02	0.04	0.03	0.05	0.04	0.03	0.02	0.01	0.01
	CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

3.3.4 Uncertainties and time-series consistency

In general, the uncertainty of emissions of the fugitive emissions from fuels sector is relatively high. The uncertainty associated with activity data is small, less than 5%, since the AD are obtained from the national energy balance and plant specific data. On the other hand, the uncertainty associated with emission factors is rather high (300%), since both the methodologies applied are of low tier (Tier 1) and the Efs are the default ones. The results of uncertainty analysis are presented in ***Table 1.9***. The detailed calculations of uncertainty are presented in Annex IV (***Tables IV.1 – IV.3***).

The time-series consistency of emissions is controlled by applying consistent methodologies in line with IPCC guidelines.

4. Industrial processes and Product use (CRT sector 2)

4.1 Overview of sector

This chapter includes information on GHG emissions from *Industrial processes* and description of the methodologies applied per source for the calculation of emissions.

According to the IPCC Guidelines, the following source categories are found in this sector:

- Mineral industry
- Chemical industry
- Metal industry
- Non-energy products from fuels and solvent use
- Electronics industry
- Emissions of fluorinated substitutes for ozone depleting substances
- Other Product Manufacture and Use

The remainder of this chapter is organized as follows. Paragraph 4.1 continues with the presentation of emissions trends from *Industrial processes*, a brief description of the methodology applied for the calculation of GHG emissions and the assessment of the completeness of the GHG inventory for the industrial processes sector. Then the following paragraphs present detailed information on the methodologies applied (including references on the activity data and the emission factors used) for the calculation of GHG emissions per source of emissions.

4.1.1 Emissions trends

In 2023, GHG emissions from *Industrial processes* account for 13.43% of total emissions (including LULUCF) and have decreased by 31.57% compared to base year emissions and decreased by 16.64% compared to the emissions of 1990 (***Figure 4.1***), while the average annual rate of increase is estimated at -0.19% for the period 1990 – present.

Emissions from *Industrial processes* are characterized by intense fluctuations during the period 1990 – 2023 reaching a minimum value of 9.11 Mt CO_2 eq in 2023 and a maximum value of 15.25 Mt CO_2 eq in 1999. The low value for 2023 is related to the impact of the pandemic to all industrial processes, the War in Ukraine, as well as to the closure of several production units in Greece. The previous lower was in 2011 and was directly linked with the economical recession, whereas the maximum value is attributed to changes in industrial production and especially in HCFC-22 production.

It should be noted that had it not been for the consumption of f-gases subcategory, the decrease of the recent years would have been much deeper. In ***Figure 4.1*** a second higher value of emissions

can be observed for 2005, also being related to HCFC-22 production, since in the next year the respective plant ceased its operation.

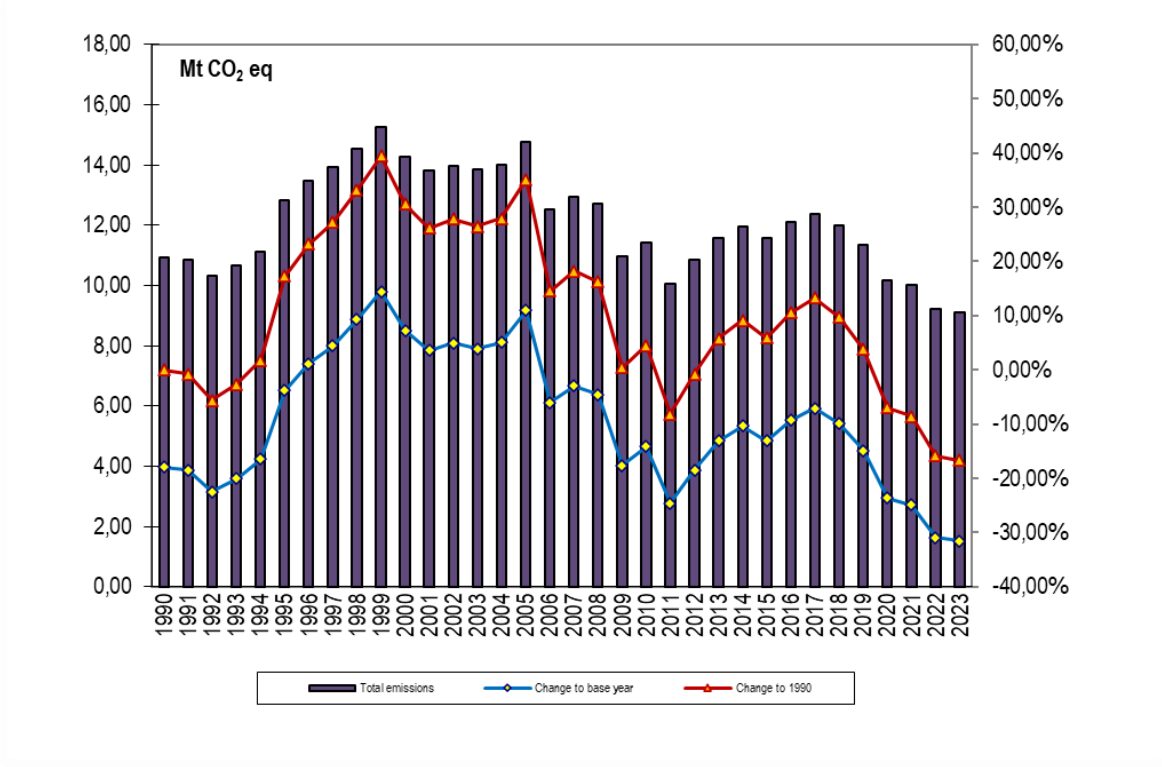


Figure 4.1 ***Total GHG emissions (in Mt CO_2 eq) from Industrial Processes for the period 1990 – 2023***

The Industrial Processes sector is responsible for emissions of carbon dioxide, nitrous oxide, methane and f-gases. Emissions per gas from industrial processes are presented in ***Table 4.1***.

Carbon dioxide represents the major GHG from industrial processes, with a contribution ranging from 48.08% to 79.90%. Overall, CO_2 emissions in 2023 decreased by 49.39% from 1990, with an average annual rate of decrease estimated at -0.02%. CO_2 emissions derive mainly from mineral products.

The contribution of f-gases to total emissions from industrial processes is also very significant, increasing from 10.66% in 1990 to 31.91% in 2002. The contribution continues to be important until 2006 where an abrupt decrease is observed (from 31.08% in 2005 to 21.21% in 2006). This abrupt decrease is totally due to the cease of HCFC-22 production in 2006. In the recent years (2007-2023) the trend is in average increasing, following the substitution of CFCs according to the protocol of Montreal, reaching a contribution of 50.35% in 2023.

Nitrous oxide emissions (from chemical industry) present a declining trend during the period 1990 – 2023, with an average annual rate of change of -4.96%. In 2013 compared to 2012 this trend accounted for 62.84% decrease, in accordance with the installation of an abatement technique for

the recovery of N_2O emissions in the sole plant operating in Greece. The annual increase for the year 2023 was -0.44% compared to 2022.

The contribution of CH_4 emissions (from chemical and metal industry) to total emissions from the sector is generally negligible, and since 2001 no emissions are reported due to the cease of ethylene and 1,2 dichloro-ethane production in 1998 and 2000, respectively, and emissions are only due to metal production. The average rate of increase is 0.11% for the period 1990-2023.

Table 4.1 GHG emissions (in kt CO_2 eq) per gas from industrial processes for the period 1990 – 2022

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2	8700,38	8604,50	8247,75	7935,01	7912,33	8393,86	8387,78	8566,59	8802,07	8708,46	8919,93
CH_4	1,55	1,63	1,56	1,64	1,69	1,76	1,83	1,81	1,73	0,72	0,59
N_2O	1.066,55	901,13	938,38	898,32	877,93	875,07	982,45	878,96	746,33	770,84	786,75
HFC	991,01	1.173,04	962,74	1.702,86	2.272,32	3.487,68	4.046,99	4.344,36	4.856,97	5.667,03	4.460,65
PFC	171,09	171,93	168,83	101,56	63,23	56,52	48,32	113,00	139,86	94,78	110,09
SF6	3,02	3,11	3,21	3,30	3,39	3,53	3,62	3,67	3,71	3,81	3,92
TOTAL	**10933,61**	**10855,35**	**10322,46**	**10642,69**	**11130,89**	**12818,42**	**13470,98**	**13908,39**	**14550,68**	**15245,64**	**14281,94**
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2	8955,75	8851,34	9015,18	8999,78	9587,22	9358,85	9257,86	8611,76	6639,74	6598,92	4922,91
CH_4	0,28	0,56	0,56	0,56	0,56	0,56	0,84	0,56	0,56	0,56	0,56
N_2O	681,89	661,59	619,38	595,58	594,52	506,82	504,49	490,20	443,39	495,42	534,97
HFC	4.079,50	4.375,21	4.112,54	4.309,68	4.503,29	2.568,97	3.058,38	3.494,70	3.805,73	4.215,53	4.480,25
PFC	75,81	79,64	80,61	79,37	82,70	78,87	93,29	107,64	82,83	117,35	100,08
SF6	4,00	4,18	4,18	4,39	6,35	8,23	9,75	7,40	5,17	6,04	5,29
TOTAL	**13797,22**	**13972,53**	**13832,46**	**13989,37**	**14774,64**	**12522,30**	**12924,61**	**12712,27**	**10977,42**	**11433,82**	**10044,06**
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	5460,97	5860,11	6155,15	5680,51	5976,73	6314,16	6160,59	5935,45	5074,98	5076,47	4347,59
CH_4	0,28	0,28	0,28	0,28	0,28	0,56	0,28	0,28	0,28	0,56	0,56
N_2O	390,96	146,16	150,09	143,67	138,37	142,19	144,04	142,85	140,72	128,60	127,49
HFC	4.864,48	5.403,54	5.505,32	5.641,71	5.844,57	5.806,45	5.559,42	5.137,08	4.816,27	4.675,61	4.558,17
PFC	133,83	156,13	121,65	108,05	122,05	113,58	122,07	123,63	133,54	111,18	87,37
SF6	5,20	5,31	5,07	5,22	5,36	5,16	5,09	5,07	5,09	5,03	5,03
TOTAL	**10855,73**	**11571,53**	**11937,56**	**11579,42**	**12087,35**	**12382,11**	**11991,49**	**11344,36**	**10170,87**	**9997,43**	**9126,21**
Year	2023										
CO_2	4403,36										
CH_4	0,32										
N_2O	126,94										
HFC	4.491,22										
PFC	87,07										
SF6	5,05										
TOTAL	**9114,57**										

Throughout the inventory years, the main sources of emissions from *Industrial processes* are **mineral products**, representing 37.10% to total IPPU emissions for year 2023, as well as production and consumption of halocarbons and SF_6 (***Figure 4.2***). Emissions show an upward trend until 1999. After 1999 this trend declines, mainly because of the gradual decrease of HCFC-22 production. A second higher value is observed in 2005, mainly as a result of the f-gases consumption contribution in combination with the cease of HCFC-22 production in the next year (2006). In the most recent years of the time series an ongoing decrease appears, resulting in an abrupt decline in 2009 mainly due to the important reduced production levels of mineral products. This is partly counterbalanced by a rather small increase in 2010, which is attributed to the system's recovery from the economic shock experienced in 2009, while in 2011 there is again a decrease in the emissions, mainly due to the decrease of the production of minerals (60.78% decrease in 2011 compared to 2005). However, since 2012 there is an increase in emissions mainly due to the increased production of cement, until 2017 after which a decrease in emissions is reported.

The contribution of Product Uses as Substitutes for ODS category to total emissions of the sector has increased considerably in the recent years (49.54% in 2023 against 0.31% in 1995) due to the replacement of Ozone Depleting Substances (ODS), from halocarbons.

Metal Industry in general has a declining contribution to the Emissions of Industrial Processes (10.82% in 1990 versus 5.24% in 2023).

Finally, the contribution of emissions from the chemical production decreased from 23.97% in 1990 to 5.0% in 2023, mainly due to the abrupt decrease in nitric acid emissions.

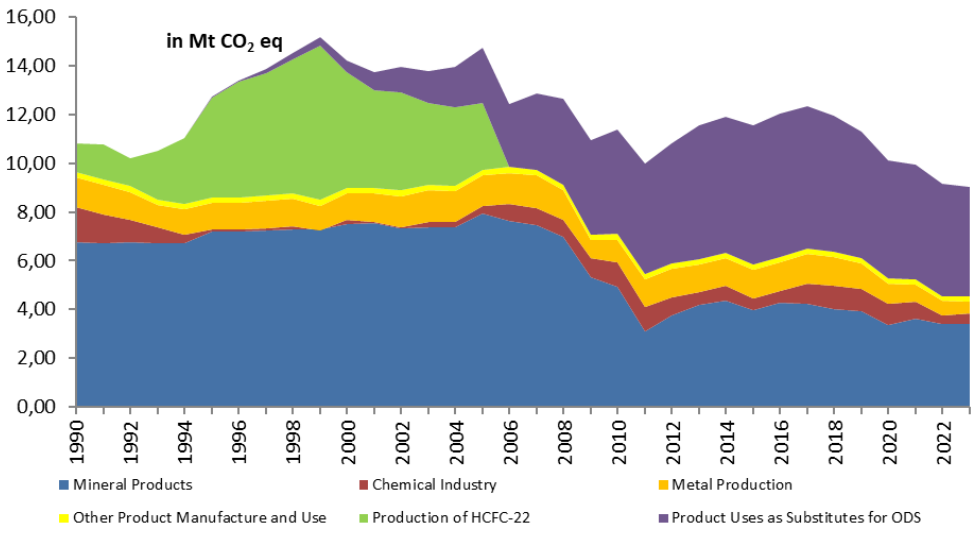


Figure 4.2 ***GHG emissions (in Mt CO_2 eq) from Industrial processes per main source category for the period 1990 – 2023***

4.1.2 Methodology

The calculation of GHG emissions from Industrial processes is based on based on the new United Nations Framework Convention on Climate Change (UNFCCC) reporting requirements. In particular, 2006 IPCC Guidelines for National GHG Inventories (2006 IPCC Guidelines) and new global warming potentials (GWPs) (UNFCCC-Decision 24/CP.19, IPCC 2006) were used in this submission. In addition, methodologies described in the 2006 IPCC Guidelines and the EMEP/CORINAIR Emission Inventory Guidebook 2013 were used whenever appropriate. In addition, depending on data availability, country specific methodologies are implemented, mostly in cases of time series recalculation due to access of updated data, but also in cases where the lack of data does not allow the use of the above mentioned methodologies.

CO_2 emissions from the majority of mineral and metal industries, as well as PFC emissions from primary aluminium production are estimated on the basis of country-specific emission factors. These emission factors derive of plant specific activity and emission data, in the context of the EU ETS, as well as from other information received by the plants and by the Hellenic Statistical Authority. All the information received is archived in the Input File, according to the Greek QA/QC system. For the *Product Uses as Substitutes for ODS* subcategory, the emission factors used are selected by the default range provided in the 2006 IPCC Guidelines, taking into account the expert judgment provided by the National Association of Refrigerating and Cooling Technicians. Default emission factors from the 2006 IPCC Guidelines are used for the estimation of GHG emissions from the rest source categories of the sector.

Activity data for the calculation of emissions from industrial processes are provided by a variety of sources. First, national production data are provided by the National Statistical Authority (El.Stat.). More specifically, in the recent years the data used in the inventory are substantially improved by the raise of confidentiality issues and the timely provision of data, after close cooperation with the ElStat, which has been achieved through various meetings and personal communication between the inventory team and the Production Statistics Section of the service. Additionally, plant specific information has been collected through questionnaires for the formulation of the NAP and verified reports under the EU ETS (years 2005-present). It should be noted that in some cases (cement production, hydraulic lime production, glass production, magnesia production, nitric acid production, primary aluminium production, ferroalloys production and HCFC-22 production) further information and data have been requested and provided by the plants. Such data are considered confidential in some cases and, therefore, might not be presented neither in the current report nor in the CRT tables, although they are used for the calculations of emissions. Instead, publicly available data are reported, wherever available, in order to help understand the timeseries trend.

For the *Product Uses as Substitutes for ODS*, data have been provided by ICAP market surveys, the National Statistics Authority (Division of Trade and Services Sector Statistics and Division of Secondary Sector Division), the National Organization of Medicines, the Public Power Corporation, the Hellenic Aerosol Association, Appliances Recycling SA, the National Association of Refrigeration Importing and Trading Companies and other industries and private companies that

are related to the production and sales of equipment containing f-gases. For the recycling amount of f-gases in refrigeration and air-conditioning, the data provided by the Appliances Recycling SA. As regards to the foam blowing and aerosols subcategories data have been collected by the respective producing industries.

Finally, in some cases data have been recalculated to ensure consistency of the time series and to improve accuracy and completeness of the sectors. This has been mostly performed in order to estimate emissions from the first time and also due to the availability of more detailed updated data.

The methodology applied for the calculation of emissions per source category is briefly presented in ***Table 4.2***, while a detailed description is given in the corresponding sections (Sections 4.2 – 4.22).

Table 4.2 Methodology for the estimation of emissions from industrial processes

	CO_2		CH_4		N_2O		F-gases	
	Method	Emission factor	Method	Emission factor	Method	Emission factor	Method	Emission factor
2.A. Mineral industry	CS, T1	CS, PS, D						
2.B. Chemical industry	T1, T1a	CS	T1	D	D,CS	D,CS		
2.C. Metal industry	CS, T1	CS, PS, D	CR	CR			T3	PS
2.D. Non-energy products from fuels and solvent use	T1	D						
2.E. Electronics industry								
2.F. Product Uses as Substitutes for ODS							CS, IE, T2	D, IE
2.G. Other Product Manufacture and Use	T1	D			OTH	OTH	CS	CS
Other								

T1. T2. T2a. T3. T3b : IPCC methodology Tier 1. 2. 2a. 3 and 3b respectively

D: IPCC default methodology and emission factor

CS: Country specific emission factor and methodology

PS: Plant specific emission factor and methodology

CR: Corrinair default methodology

Key categories

The key categories for 2022 (either with or without LULUCF) included in *Industrial processes* are presented in ***Table 4.3*** (see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations). It should be noted that the number of key categories in the IP sector has been substantially increased as a result of the breaking-up of larger categories in the key categories analysis, following the recommendations of the 2010 Expert Review Team.

Table 4.3 Key categories from industrial processes in the year 2022

Source category	Gas	Level assessment	Trend assessment
Cement Production	CO_2	☒	☒
Ammonia Production	CO_2		☒
Aluminium Production	CO_2	☒	
Nitric Acid Production	N_2O		☒
Other	CO_2	☒	☒
Refrigeration and Air conditioning	Aggregate F-gases	☒	☒

Uncertainty

The results of the uncertainty analysis are presented in Paragraph 1.7, while the detailed calculations are presented in Annex VII. Moreover, in each of the sources described below the uncertainty will be discussed in the respective paragraph.

4.1.3 Completeness

Table 4.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in the industrial processes sector.

The completeness has generally been improved in the last inventories.

Table 4.4 Industrial processes – Completeness

	CO_2	CH_4	N_2O	HFC	PFC	SF_6
A. Mineral Industry						
1. Cement production	☒					
2. Lime production	☒					
3. Glass Production	☒					
4. Other Process Uses of Carbonates						
Ceramics	☒					
Other uses of Soda Ash	☒					
Non-metallurgical Magnesium Production	☒					
Other	☒					
B. Chemical industry						
1. Ammonia production	☒	NA	NA			
2. Nitric acid production			☒			
3. Adipic acid production	NO		NO			
4. Caprolactam, Glyoxal and Glyoxylic Acid Production	NO		NO			
5. Carbide Production	NO	NO				
6. Titanium Dioxide Production	NO					
7. Soda Ash Production	NO					
8. Petrochemical and Carbon Black Production	☒	☒				
9. Fluorochemical Production				NA		
10.Other						
Sulfuric acid production	NA	NA	NA			
Hydrogen Production	☒	NA	NA			
C. Metal production						
1. Iron and steel production	☒	☒				
2. Ferroalloys production	☒	NA				
3. Aluminium production	☒				☒	
4. Magnesium Production	NO				NO	NO
5. Lead Production	☒					
6. Zinc Production	☒					
D. Non-energy Products from Fuels and Solvent Use						
1. Lubricant Use	☒	NA	NA			
2. Paraffin Wax Use	☒	NA	NA			
3. Other						
Solvent use	☒	NA	NA			
Use of urea as a catalyst	☒	NA	NA			
Road paving with asphalt	NE	NA	NA			
Asphalt roofing	NE	NA	NA			
E. Electronics Industry						
F. Product Uses as Substitutes for ODS						
1. Refrigerating and air conditioning equipment				☒	☒	NO

2. Foam blowing				☒	NO	NO
3. Fire Protection				☒	NA	NO
4. Aerosols				☒	NO	NO
5. Solvents				NA	NO	NO
6. Other Applications				NA	NA	NA
G. Other Product Manufacture and Use						
1. Electrical Equipment				NA	NA	☒
2. SF6 and PFCs from Other Product Use						
3. N2O from Product Uses			☒			
4. Other	☒	NA	NA			
H. Other	NA	NA	NA			

NE: Not Estimated
IE: Included Elsewhere
NO: Not Occurring
NA: Not Applicable

4.2 Cement Production (CRT Source Category 2.A.1)

4.2.1 Description

Emissions of CO_2 occur during the production of clinker, which is an intermediate component in the cement manufacturing process. CO_2 emissions are attributed to the calcination of limestone (mainly $CaCO_3$), to produce lime (CaO) and carbon dioxide as a by-product.

Cement production (CO_2 emissions) is a key category by level and trend assessment. CO_2 emissions from cement production in 2023 (***Table 4.5***) accounted for 32.90% of total GHG emissions from industrial processes.

Table 4.5 CO_2 emissions from clinker production (in kt) for the period 1990 – 2023

Year	Clinker production (kt)	CO_2 emissions (kt)
1990	10645.13	5761.69
1991	10561.79	5715.77
1992	10831.27	5861.14
1993	10851.82	5875.03
1994	10930.92	5916.41
1995	11743.73	6356.39
1996	11773.83	6374.25
1997	11831.56	6407.69
1998	11789.07	6383.24
1999	11761.21	6366.36
2000	12071.73	6536.76
2001	12130.78	6565.92
2002	11666.18	6313.27
2003	11754.73	6368.13
2004	11754.73	6363.90
2005	12442.36	6791.12
2006	12244.24	6599.22
2007	12035.08	6406.63
2008	11361.40	6053.53
2009	8649.32	4581.72
2010	7926.64	4208.60
2011	4569.17	2430.43
2012	5856.10	3099.30
2013	6915.19	3638.96
2014	7233.53	3821.93
2015	6554.29	3467.28
2016	7086.34	3772.24
2017	7088.09	3685.21
2018	6548.11	3419.47
2019	6429.11	3360.21
2020	5744.65	2977.78

2021	6117.1	3166.78
2022	5646.03	2904.92
2023	5801.66	2998,49

4.2.2 Methodological Issues

During the inventory preparation the calculation of CO_2 emissions from cement production is very important, as this is a key category by both trend and level assessment.

For the years 2005-2023 detailed data have been accessed via the verified EU ETS reports of the plants. These data refer to the quantities of carbonate raw material ($CaCO_3$, $MgCO_3$) used for the production of clinker. The general equation used for each of the eight operating cement plants is described by the following equation:

$$CO_2\text{Emissions} = \sum_i \left(EF_i \cdot M_i \cdot F_i\right) - M_d \cdot C_d \cdot \left(1 - F_d\right) \cdot EF_d$$

where, EF_i is the emission factor for the particular carbonate I, M_i is the weight or mass of carbonate I consumed in the kiln, F_i is the fraction calcination achieved for carbonate I, M_d is the weight or mass of CKD not recycled in the kiln, F_d is the fraction calcination achieved for the CKD not recycled to the kiln, EF_d is the emission factor for the non-calcined carbonate in CKD not recycled to the kiln.

As regards to the emissions from the non-calcined CKD not recycled to the kiln, these have already been included in the emissions from carbonates reported by the plants, therefore an assumption of F_d=1 has been used to avoid double counting.

Emissions prior to 2005 in the past were calculated using the Tier 2 methodology, based on clinker production. Following the change of the methodology to Tier 3, and according to the 2006 IPCC Guideliness (plant specific data became available in the context of EU ETS reports), the overlap methodology has been used in order to ensure the consistency of the time-series. This was achieved as for the years 2005-2007 emissions have been estimated by both methods (Tier 2 and the Carbonates Method). More details are provided in the NIR 2009, p. 125.

It should be noted that for the emissions estimated using the Tier 2 methodology (that is previous to the 2008 submission), the parameters of CaO and MgO content were determined using plant specific information collected during the formulation of NAP (See also NIR 2007, 2008 etc.).

In the recent years (2008 – 2022) the plants also reported emissions from non-carbonate carbon (organic carbon). In 2014 submission, there was a recalculation of emissions for the years prior to 2008, using the overlap methodology in order emissions from non-carbonate carbon sources (TOC) to be considered for the whole time-series.

For reasons of consistency between both the previous years and the other countries, the activity data of the more recent years (2005-2023) are still expressed in kt of clinker produced.

4.2.3 Uncertainties and time-series consistency

The uncertainty of the current category's estimations is quite low (2% for EF and AD), since the emissions are plant-specific and the reports of the emissions are being verified by accredited verifiers (all the cement plants of Greece are members of the EU ETS).

As regards to the time series, data are generally well in line in terms of methodology. This has been achieved by making use of the overlap methodology in 2009, in order to ensure the consistency of the time series (up to that year, emissions have been calculated using the Tier 2 and the country specific carbonates methodology).

It is quite clear from the Chart in ***Figure 4.3*** that the cement production is experiencing intense reduction for the years 2009 to 2011, which is attributed to the economic recession that has been very important in the Construction Sector of Greece. It should be mentioned, actually, that the decrease of 2011 is much more intense than the one of 2008 to 2009 (-24.31% versus -42.25%, respectively), depicting the reduction of the number of construction (-23.95% versus -54.69%, respectively. In 2023 emissions presented an increase of 3.22% compared to 2022 emissions.

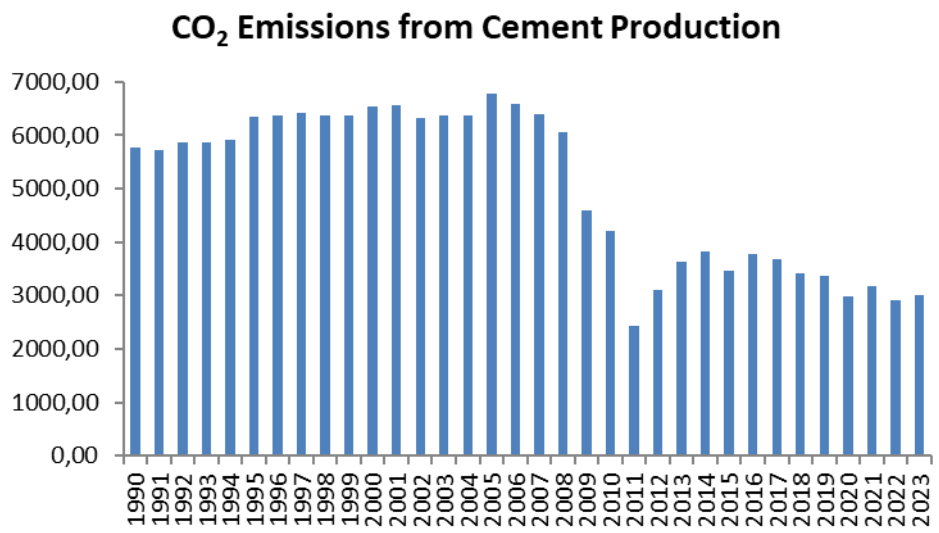


Figure 4.3 ***CO_2 emissions (in kt) from Cement Production for the period 1990 – 2023***

During the years 1990-2005, emissions show some low-level fluctuations (***Figure 4.2***). In general, annual variations of clinker production and, as a result, of CO_2 emissions are rather low, since a decrease in the domestic demand is counterbalanced by increased exports. However, there has been an abrupt shift in the production level between 1994 and 1995, amounting to 1 million tonnes of clinker produced. The shift was due to an increase of production in one particular plant, as result of a change in ownership, which led to increased use of already existing production capacity. Also, in the years 2005-2008 a general decrease of emissions is observed, a decrease that becomes very abrupt in 2009 probably due to the economic recession of the country. The decreasing trend remains in 2010 and become even deeper in 2011.This is also verified by the decreased number of

new constructions, although in years 2012 to 2014 there is an increase in emissions derived from cement production. In 2017 a decrease in emissions was recorded compared to 2016.

The IEF of 2017 is close to the mean IEF of the previous years, probably because of the fact that the carbonates percentage of the raw materials is close to the mean values of previous years. The average CaO and MgO content of clinker, as well as the percentage of CaO/MgO, for the years 2005-2019, as provided by the plants, is presented in ***Table 4.6***. Any fluctuations, therefore, of the emission factors can be explained according to the fluctuations of the percentages of calcium and magnesium oxides in the clinker. However, it should be mentioned that the CaO/MgO content of clinker is not being used as an assumption for EF estimation.

Table 4.6 CaO and MgO content of clinker (2005-2023)

Year	CaO content of clinker (%)	MgO content of clinker (%)	CaO/MgO (%)
2005	64.68	2.93	22.08
2006	64.65	3.03	21.34
2007	64.47	3.26	19.76
2008	64.73	3.25	19.94
2009	65.00	2.99	21.74
2010	65.21	2.74	23.77
2011	65.31	2.81	23.21
2012	58.14	2.04	28.57
2013	51.77	2.08	24.95
2014	51.84	1.97	26.38
2015	52.01	1.95	26.59
2016	52.37	1.92	27.06
2017	51.85	1.97	26.32
2018	51.65	1.96	26.52
2019	51.48	1.96	26.33
2020	51.60	1.94	26.67
2021	51.77	1.94	26.03
2022	51.79	1.94	26.76
2023	51.77	1.94	26.75

4.2.4 Source-specific QA/QC and verification

In order to perform quality assurance activities, the total clinker produced reported by the plants is also checked with the value provided by the ElStat. In general, the two sources agree, especially in the recent years where the produced clinker is additionally requested by the plants as a part of Greece QA procedures. Additional QA/QC procedures include the collection of additional information for the Construction sector, as provided by ElStat. In this framework the number of new constructions and the Production Index in Constructions are used as additional indications of the overall trend.

4.2.5 Recalculations

No recalculations have been performed during this submission.

4.2.6 Planned improvements

The current submission can be considered satisfactory.

4.3 Lime production (CRT Source Category 2.A.2)

4.3.1 Description

Lime production leads to carbon dioxide emissions because of the calcination of limestone ($CaCO_3$) or dolomite ($CaCO_3.MgCO_3$) to produce lime or dolomitic lime. Lime production in Greece is based on limestone.

$$CaCO_3 \text{ (high-purity limestone)} + \text{heat} \rightarrow CaO \text{ (quicklime)} + CO_2$$

CO_2 emissions from lime production in 2023 (***Table 4.7***) does not constitute a key category, and accounted for 1.65% of total GHG emissions from *Industrial processes*. Emission factors are characterized by fluctuations, mainly because of the difference between plant-specific data and ElStat data.

Table 4.7 ***Production of lime (in kt) and CO_2 emissions (in kt) from lime production for the period 1990 – 2023***

Year	Lime production(kt)	CO_2 emissions (kt)	IEF
1990	491.03	404.00	0.82
1991	476.17	391.78	0.82
1992	461.31	379.55	0.82
1993	442.00	362.95	0.82
1994	427.58	351.25	0.82
1995	442.12	362.35	0.82
1996	452.06	370.07	0.82
1997	464.71	377.57	0.81
1998	508.92	414.33	0.81
1999	540.98	445.77	0.82
2000	497.93	411.17	0.83
2001	477.76	394.81	0.83
2002	495.27	408.84	0.83
2003	435.56	359.59	0.83
2004	435.79	359.45	0.82
2005	505.76	403.16	0.80

2006	489.30	408.85	0.84
2007	555.97	468.98	0.84
2008	451.11	341.76	0.76
2009	380.77	288.78	0.76
2010	328.64	229.96	0.70
2011	263.64	193.00	0.73
2012	272.66	208.54	0.76
2013	255.62	181.16	0.71
2014	214.92	176.46	0.82
2015	217.72	162.94	0.75
2016	244.22	173.75	0.71
2017	248.04	173.15	0.70
2018	235.48	210.22	0.89
2019	228.95	199.21	0.87
2020	229.64	166.95	0.73
2021	269,67	192.68	0.71
2022	254.34	176.68	0.89
2023	182.34	150.46	0.83

4.3.2 Methodology

For years 2005 – 2023, the calculation of carbon dioxide emissions from lime production is based on the collection of plant-specific data on the type (s) and quantity(ies) of carbonate(s) consumed to produce lime, as well as the respective emission factor(s) of the carbonates consumed. The emissions are estimated according to the following equation, making use of plant-specific data provided by the verified reports of the plants under the EU ETS:

$$CO_2 Emissions = \sum_i \left(EF_i \cdot M_i \cdot F_i \right) - M_d \cdot C_d \cdot \left(1 - F_d \right) \cdot EF_d$$

where, EF_i is the emission factor for the carbonate I, M_i is the weight or mass of carbonate I consumed, F_i is the fraction calcination achieved for carbonate I, M_d is weight or mass of LKD, C_d is the weight fraction of original carbonate in the LKD fraction, F_d is the fraction calcinations achieved for LKD and EF_d is the emission factor for the non-calcined carbonate.

The principal carbonates detected in the Greek lime industry were $CaCO_3$ and $MgCO_3$. The emission factor for $CaCO_3$ is 0.44 and for $MgCO_3$ 0.522.

As regards to the emissions from the non-calcined carbonate remaining in LKD, they have already been included in the emissions from carbonates reported by the plants, therefore an assumption of F_d=1 has been used to avoid double counting.

The lime production of Greece refers to high-calcium (hydrated and non-hydrated) and hydraulic lime. Both values (activity data) are provided by the ElStat for the years 1993-2020, whereas for the years 1990-1993 the missing data have been calculated using the trend extrapolation method as described in the 2006 IPCC Guidelines. For years 1990-1992 as the emissions were missing in order to calculate them an average emission factor of the years 1993-2009 was used. The Efs for the years 1993-2004 were calculated from the ElStat activity data and the calculated emissions based at first on a tier 2 methodology. For these years, according to the Tier 2 methodology suggested in the 2006 IPCC guidelines the EF of 0.59 kg CO2/kg lime was used for hydraulic lime and 0.75 kg CO2/kg lime for high calcium lime. Since then, these data were recalculated in 2009 to tier 3 methodology (based on the years 2005-2009 which were under the ETS system).

The IEF shows important fluctuations, as it has been already stated in previous NIRs. This can be attributed to the fact that activity data reported are calculated using ElStat data for hydrated, non-hydrated and hydraulic lime, although the emissions are calculated according to the verified ETS reports, as provided by the plants. These fluctuations can also be attributed to the carbonates content of the raw material (***Figure 4.4***).

Lime production in the national statistics is reported as non-hydrated lime, hydrated lime and hydraulic lime, as mentioned above. The hydrated lime production data are converted to non-hydrated lime using the correction for the proportion of hydrated lime, using a water content of 28%.

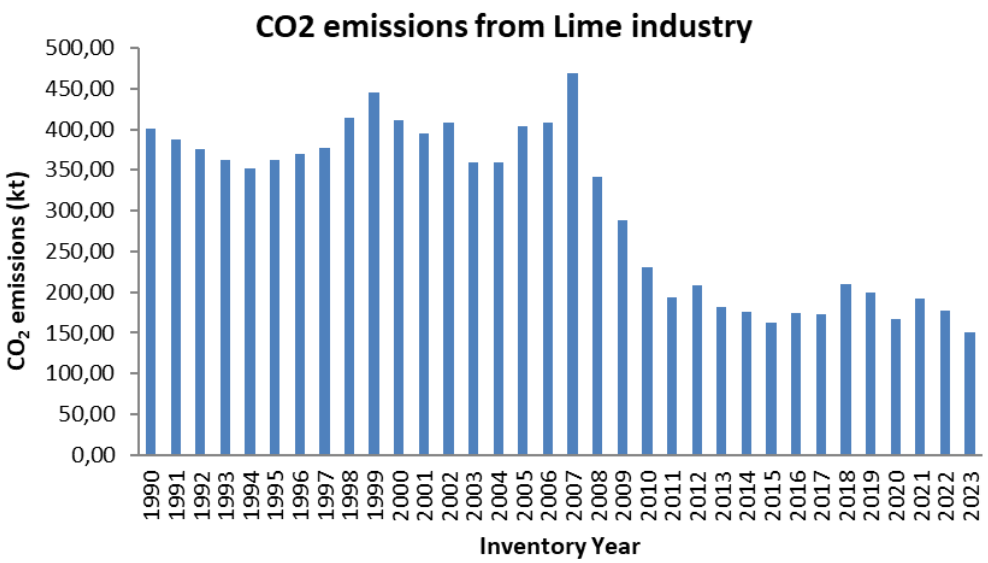


Figure 4.4 ***CO_2 emissions for lime production for the period 1990 – 2023***

4.3.3 Uncertainties and time-series consistency

The uncertainty of the estimate is medium, although data derive from plant-specific, detailed reports of the plants in the context of the EU ETS. A value of 6% has been used for the emission

factor, accounting mainly for the uncertainty of lime composition (although data are available for the recent years, for the previous this was not the case). As regards to AD, a value of 5% has been used, provided the fact that the uncertainty of plant-specific weighting materials is at the level of 1-3%, while minor errors may derive from assuming 100% carbonate source from limestone. All the lime plants that report to the El Stat report also under the EU ETS, according to information received by the first. It should be noted that these reports are also verified by external auditors, according to the basis of the Hellenic ETS system. Finally, as regards to the sugar industry of Greece data indicate that indeed 3 out of 5 plants produce lime, but the CO_2 produced by the cracking of the carbonates is fully bound during the production process. In particular, hydrated lime is added to the sugar juice in order to raise the pH and to react with the impurities. Afterwards CO_2 is transmitted in the sugar pulp, where sugar lime is decomposed, and insoluble calcium carbonate sediments are formed.

As regards to the time series consistency, the emissions have been recalculated in 2009 to improve the consistency between the different methods used. This has been performed by making use of the overlap methodology, as suggested in the IPCC Guidelines. The information over this recalculation can be found in the 2009 NIR. In 2013 submission a recalculation has also been performed as an error in the calculation of the conversion of hydrated lime to non-hydrated lime was detected. Correction for the moisture proportion of hydrated lime, as described in the IPCC guidelines, was used and a recalculation was then applied for the whole time series, according to the overlap methodology.

In general emissions show some fluctuations throughout the years. This is due to the production levels, as well as to the EF, that is calculated based on the reporting of the plants (the inclusion of minor carbonates changes the IEF from year to year). Especially after 2008, important decreases depict the economical recession of the infrastructure sector, which is counter-balanced during the last years.

4.3.4 Source specific QA/QC and verification

The source specific quality control is being performed by implementing the Tier 3 methodology, using as well the ElStat production data. Comparing to the default factors the IEFs are in an accepted range and are closer to the stoichiometric factor of high calcium lime (0.785). However, for the previous years the emission factor is closer to the emission factor used for dolomite lime than for the high calcium one. During the review submitted in 2017 the ERT noted that the CO2 IEF values from lime production for Greece for the period 1990–2006 are very high in comparison with those of other European countries with similar production systems. Greece in order to improve time-series consistency, in 2013 has recalculated the emissions for the years prior to 2005, based on the available data from the EU ETS for the years 2005–2009 using the overlap technique described in the 2006 IPCC Guidelines. The high values of the IEF stem from the higher values of the EFs for the years 2005–2009 compared with those of recent years from the verified EU ETS reports.

In years 2005-2023 the emissions are provided by the verified ETS reports of the respective plants. In the EU ETS reports the lime production is reported as total lime production. However, some of the plants, although they do report all the emissions and emission factors, they do not report the lime production. For this reason, the inventory team decided to acquire production data by the national Statistical authority (ElStat), as they are presented separately as hydrated and non-hydrated lime as well as hydraulic lime. However, for the last years 2012-2020 it is noticed that Plant Specific data should be used over ElStat data as they are more detailed. Therefore, there are certain fluctuations in emission factors which can be attributed to the fluctuations in activity data. Regarding 2020 AD, the Elstat production data are considered provisional in this submission as reported by Elstat, therefore next year they will be updated with the new data and the IEF will also be updated.

Concerning previous years, according to the reports received, three of the plants do mention the existence of additional sources of carbon (organic carbon, K_2CO_3 and/or Na_2CO_3) in year 2007, while in the next year no such use has been reported. As a result, fluctuation of the IEFs appear in the timeseries for previous years as well.

4.3.5 Recalculations

A recalculation was performed in AD and emissions in 2022 due to an error in previous submission. Emissions reported in 2022 are 176.68 instead of 253.69 (reported previously).

4.3.6 Planned improvements

The current submission can be considered satisfactory.

4.4 Glass Production (CRT Source Category 2.A.3)

4.4.1 Description

Glass production leads to carbon dioxide emissions due to the thermal decomposition of carbonate compounds included in raw materials.

CO_2 emissions from glass production are not a key source and have decreased by 21.53% compared to 1990 levels, with a contribution of 0.17% of the total GHG emissions from Industrial processes.

4.4.2 Methodology

In the recent years, the estimation of carbon dioxide emissions from glass production is based on accounting for the carbonate input to the glass melting furnace, by using the following equation:

$$CO_2 Emissions = \sum_i \left(M_i \cdot EF_i \cdot F_i \right)$$

where, M_i is mass of carbonate I consumed, $EF_i$is the emission factor for carbonate I, and F_i is the fraction of calcination achieved for the particular carbonate. The reported carbonates are Na_2CO_3, $CaCO_3$ and $MgCO_3$ with emission factors 0.415, 0.44 and 0.522, respectively. The implied emission factor for 2020 is 0.142 t/t.

Since February 2006 there is only one plant operating in Greece, whereas since 2005 this plant used to have two factories. Production data have been given for both factories for years 2005-2006 and for the only plant operating for the years 2007-2023. Also, for the years 2005-2023 the reports in the EU ETS context have been extensively used.

Activity data (glass production) for the period 1990 – 1992 are provided by the ElStat, while activity data for the period 2001 – 2004 were collected (through questionnaires developed according to the guidelines described in the Commission Decision 2004/156/EC) in the framework of the formulation of the NAP for the period 2005 – 2007, according to the EU Directive 2003/87/EC. Activity data for the period 1993 – 1999 were estimated by means of a linear interpolation due to the lack of sufficient official data for that period.

Table 4.8 Glass production (in kt) and CO2 emissions (in kt) for the period 1990 – 2023

Year	Glass Production (kt)	CO_2 emissions (kt)
1990	134.94	20.20
1991	124.57	18.65
1992	97.26	14.56
1993	99.71	14.92
1994	108.55	16.25
1995	117.32	17.56
1996	126.10	18.88
1997	134.87	20.19
1998	143.65	21.50
1999	152.42	22.82
2000	161.20	24.13
2001	169.91	25.43
2002	170.75	25.56
2003	147.27	22.04
2004	138.16	20.68
2005	129.54	18.16
2006	103.09	14.50
2007	115.91	17.38
2008	116.26	17.15

2009	93.66	13.33
2010	113.64	15.16
2011	87.62	11.40
2012	116.01	15.59
2013	114.47	16.65
2014	109.26	16.82
2015	106.27	16.31
2016	104.27	16.70
2017	99.38	17.60
2018	116.65	17.20
2019	118.07	16.80
2020	100.74	16.58
2021	120.01	16.68
2022	119.68	17.95
2023	113.15	15,85

4.4.3 Uncertainty and time-series consistency

The estimated uncertainty concerning the glass production category is relatively low. The emission factor is stoichiometric, corresponding to a 3% uncertainty value, while the uncertainty estimate for the AD mainly lays on the uncertainty of the plant-level weighting of the materials and is considered to be 5%.

As regards to the time-series consistency, data have been recalculated in 2009 using the overlap methodology. Information on the performed recalculations is given in the 2009 NIR submission. It should be noted that the methodology used is in line with the 2006 IPCC Guidelines.

As it can be observed in ***Figure 4.5***, the decrease in CO_2 emissions in 1992 can be attributed to the fact that flat glass production (for glass panes) ceased in 1992, according to an available sector study[1], as there was a continuous decrease in production of flat glass, due to the decreasing domestic demand and the increasing competition with the international markets and therefore the producing company ceased its operation.

Emissions for the period 2002-2006 show a continuous decrease. This slope is justified by the fact that one of the two glass industries that were operating in Greece at that period was about to close and has reduced significantly the annual glass production. Moreover, the other glass industry had invested in plants of neighbour countries, making easier the import of glass to Greece.

[1]Development of nine (9) market surveys for SMEs, Sector: “Glass Manufasture and Glass Products”. EOMMEX

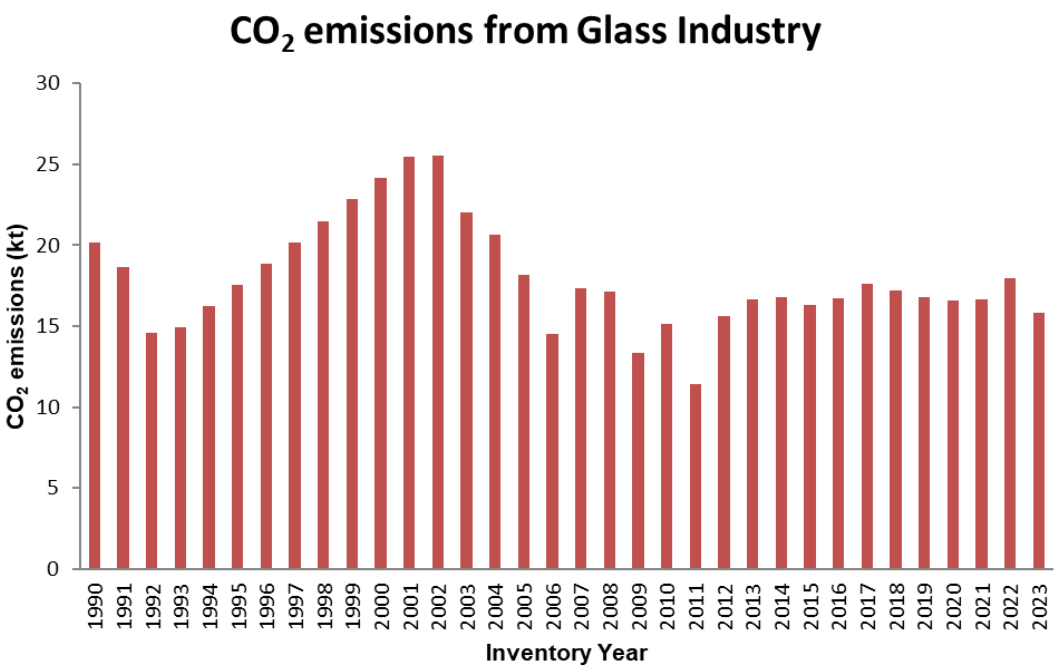


Figure 4.5 CO_2 emissions (in kt) from Glass Production for the period 1990 – 2023

Emissions in 2008 decreased by 1.27% with regards to 2007. This increase is not well in line with the slight increase observed in the production level (by 0.30%). According to the activity data this difference is due to the fact that the carbonate contents of soda and of dolomite are lower than the ones reported in 2007.

Emissions in 2009 have decreased by 22.28% with reference to 2008, with a similar decrease in the production levels, as a result of the economic crisis in the *Industrial Processes* Sector of Greece.

In 2010 this decrease is partially counterbalanced with an increase of 13.73%, as it happens with other Categories of the IP Sector. However, the increase in production of glass was equal to 21.3%, which is in line with the cullet ratio provided by the plant, which was higher by 14.28% for this year. After a direct communication with the sole plant operating in Greece the inventory team was informed that the cullet ratio used each year for the production of new glass shows variations, which could lead to a smaller increase in CO_2 emissions, when compared to the production increase.

In 2012 an increase in CO_2 emissions of 36.80% was observed, in accordance with the increase in production level equal to 32.39%. The cullet ration used in 2012, according to the data provided by the plant, was 9.97% less than in 2011. In 2013 CO_2 emissions increased by 6.79% since 2012 accompanied by a decrease of cullet ration and a small decrease of production equal to 1.32%, followed by an increase in emissions in 2014 by 1.01% compared to 2013, while the production level decreased by 4.56%.

Finally, emissions in 2019 decrease slightly by 2.39% compared to 2018 levels, followed by a slight decrease of 1.28% in 2020 compared to 2019 levels. In 2021 emissions presented a 0.61%

increase since 2020 and an additional increase of 7.6% between 2021 and 2022, followed by a decrease -11.7% between 2022 and 2023.

4.4.4 Source specific QA/QC and verification

The category-specific QA/QC procedures regard the estimation of emissions with different tiers, since all the data refer to only one plant operating in Greece. The default emission factor as described in the CORINAIR Guidelines (SNAP 03314-03317) is 0.15 kg CO_2/kg glass produced for the case of container glass, leading to emissions that are very close to the ones described by the plant. New data were requested and acquired concerning the actual percentage of the cullet ratio for the last years, after 2008. The percentages result from four types of glass produced in the specific plant, namely blue, white, amber and green. This information, along with the variations in production level, could explain the fluctuations in CO_2 emissions that are observed during the last years.

4.4.5 Recalculations

No recalculations have been performed in this submission.

4.4.6 Planned improvements

The current submission can be considered satisfactory for the time being.

4.5 Other Process Uses of Carbonates (CRT Source Category 2.A.4)

4.5.1 Description

Limestone ($CaCO_3$) and dolomite ($CaCO_3.MgCO_3$) are basic raw materials having commercial applications in a number of industries including agriculture, construction and environmental pollution control. In industrial applications involving the heating of limestone or dolomite at high temperatures, CO_2 is generated.

CO_2 emissions from Other Process Uses of Carbonates do not constitute a key category, according to the results of the key analysis carried out in the present inventory. Emissions in 2023 (***Table 4.9***) accounted for 2.37% of total GHG emissions from *Industrial processes*.

Table 4.9 ***Limestone use and magnesite consumption (in kt) and CO2 emissions (in kt) for the period 1990 – 2023***

Year	Limestone& magnesite consumption (kt)	CO_2 emissions (kt)	IEF
1990	1,273.08	589.53	0.46
1991	1,240.05	570.38	0.46
1992	1,139.29	520.71	0.46
1993	1,038.94	477.33	0.46
1994	907.60	418.81	0.46
1995	967.96	449.80	0.46
1996	895.08	413.60	0.46
1997	972.44	450.17	0.46
1998	1,029.96	475.74	0.46
1999	976.92	450.31	0.46
2000	1,132.80	520.66	0.46
2001	1,230.56	563.43	0.46
2002	1,228.78	564.80	0.46
2003	1,314.54	599.20	0.46
2004	1,346.67	612.99	0.46
2005	1,599.14	714.33	0.45
2006	1,323.07	613.24	0.46
2007	1,238.64	578.58	0.47
2008	1,180.19	545.46	0.46
2009	964.41	437.49	0.45
2010	1,040.15	466.92	0.45
2011	1,069.14	473.74	0.44
2012	937.11	414.75	0.44
2013	792.04	333.43	0.42
2014	800.42	344.18	0.43
2015	724.54	310.20	0.43
2016	702.89	308.98	0.44
2017	843.55	370.76	0.44
2018	806.23	360.74	0.45
2019	793.68	355.26	0.45
2020	468,02	207,56	0,44
2021	576,36	245,02	0,43
2022	591,95	243,30	0,41
2023	523,89	216,29	0,41

4.5.2 Methodology

The present inventory includes emission estimates following four broad source categories:

2.A.4.a Ceramics,

2.A.4.b Other uses of soda ash,

2.A.4.c Non-metallurgical magnesia production, and

2.A.4.d Other uses of carbonates.

The 2.A.4.d sub-category includes limestone use in metal production (primary aluminium), SO_2 scrubbing and mineral wool.

CO_2 emissions are estimated according to the following general equation:

$$CO_2 Emissions = \sum_i \left(M_i \cdot EF_i \cdot F_i \right)$$

where, CO_2 emissions refer to the emissions from ceramics, other uses of soda ash, non-metallurgical magnesia production, primary aluminium, SO_2 scrubbing and mineral wool, M_i is mass of carbonate I consumed, $EF_i$is the emission factor for carbonate I, and F_i is the fraction of calcination achieved for the particular carbonate.

In relation to the estimation of CO_2 emissions from limestone and dolomite use, the following are noted:

- **Ceramics production**: Carbonates consumption data (in the context of the ETS reports) have been used to estimate emissions in the years 2005-present. Activity data refer to $CaCO_3$ and $MgCO_3$ consumption (emission factors 0.44 and 0.522 respectively). Limestone consumption data are available also for the period 2000-2004 (questionnaires of the plants under the NAP formulation). Missing data for the period 1990 – 1999 were filled in on the basis of the ceramics production trend reported by the ElStat for the same period. It is also interesting that more than half of the ceramics plants operating in Greece have declared zero emissions in 2015, as a result of their decreased market activity. This suggests that the effects of the economic recession refer to a more limited number of stronger plants, rather than a one-way decrease in emissions. The fluctuation in IEF since 2005 can be attributed to the Efs of carbonates, oxides and organic carbon ($CaCO_3$, CaO, $MgCO_3$,MgO, organic carbon, K_2CO_3, Na_2CO_3, $BaCO_3$) used in the ceramics production procedure.
- **Soda ash use**: Carbon dioxide is considered to be emitted during the soda ash use in:

  pulp and paper industry, for the production of NaOH based on the reaction:

  $Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$

  (In Greece is more possible that NaOH is directly purchased by the plants)

b. desulphurization of fuels

(All the Greek plants use limestone in the SO_2 scrubbing process, as it is already reported in the respective ETS reports –see also below).

c. asapH and waterhardnessregulator, on the basis of the following reaction:

$Ca^{++} + Na_2CO_2 \rightarrow CaCO_3 + 2Na^+$

In this case the Na++ ions remain dissolved in the water while the $CaCO_3$ is in the form of sediment that precipitates. In these cases there are no CO_2 emissions.

d. indetergents

In this case soda ash is used for three reasons:

- as an additive for the pH regulation at 9.0-9.5. This assures the optimum application of the detergent and produces small amounts of CO_2 based on the reaction:

$H^+ + Na_2CO_3 \rightarrow 2Na^{++} + H_2O + CO_2$

- as an additive for water hardness' regulation, aiming to the formulation of Ca and Mg carbonates based on the reaction provided above.

- as a raw material for silicates production in composite detergents. Sodium silicate is the produced in electic furnaces based on the reaction:

$Na_2CO_3+SiO_2 \rightarrow Na_2SiO_3+CO2$,

resulting in CO_2 emissions.

e. chemicals production

In this case soda ash is used in the production of sodium phosphates, sodium silicates, chrome chemicals and photographic chemicals.

f. glass production (included in CRT Source Category 2.A.3 and described in Paragraph 4.4)

The required activity data on imports and exports of soda ash at a national level are provided by the Hellenic Statistical Authority (ElStat). Provided there is no soda ash production in Greece the annual national consumption refers to the 'Imports-Exports' value. Data referring to years previous to 1998 are not easily accessible since they are available only on hard copies and therefore are estimated using the Trend Extrapolation methodology, as described in the 2006 IPCC Guidelines. The trend extrapolation has been based on the years 1998-2009. The wide range of years was considered satisfactory as a basis for applying the trend extrapolation methodology.

The soda ash used by the glass industry is then removed, as it is already accounted in emissions from Glass Production. In order to estimate the emissions, the following should be mentioned:

-For years 2005-present the consumption is estimated based on the data provided by the one plant operating in Greece. Data for 2022 are considered provisional and will be updated during the next submission.

-For years 2001-2004, Na_2CO_3 actual consumption is provided by the 1st NAP. In view of the trend changes and to avoid the extended use of trend extrapolation method, the surrogate

method has been used to estimate the logistical soda ash quantity used based on the actual quantity reported by the plants.

-For years previous to 2001 no detailed data are available on glass industries and the same methodology cannot be applied. Trend interpolation is used in line with the IPCC Guidelines.

-Data on glass production are available from previous inventories for years 1990-1993, as provided by the ElStat (for the following years these data are not available due to the change of PRODCOM units and/or codes from quantities to pieces of various unknown sizes and types). The plant specific data acquired through personal communication for the years 2005-2009 are used for the estimation of the relevant quantities using the surrogate method, so as to avoid, to the point possible, the extended use of linear interpolation, as suggested in the 2006 IPCC Guidelines.

The EF used is the default one suggested in the IPCC Guidelines (0.415 t/t soda ash used). It should be noted that in the 1st National Allocation Plan (NAP) three glass factories report under glass industry (two operating for the same firm), while since 2006 there is only one left operating in Greece.

- **Magnesia production:** Emissions are estimated using information for the plants operating in Greece for the years 1999-present and the produced quantities of magnesia that have been provided by the Hellenic Statistical Authority for the years 1990-1998. The calculation of emissions for the whole time-series was performed according to the available data per year, as described in the following:

Years 2013-present: for this period both activity data and emissions derive from the EU ETS reports of the relevant plants operating in Greece.

Years 2005-2012: for that period the following data were provided by the single plant operating in Greece:

-the quantities and the chemical analysis of the magnesite used in the kilns

-the production of magnesia (both types as a total)

-detailed calculations of CO_2 emissions

The emissions reported for that period were the ones provided by the plant, which have been verified by external verification bodies and reviewed by the competent authorities of Ministry of Environment and Energy (MEEN), in the context of EU Directive 2009/29/EC.

Based on the $CaCO_3$ and $MgCO_3$ contents of the magnesite provided for the years 2005-2008, the implied emission factor (tn of CO_2/tn of magnesite) has been estimated in September 2010, which ranges between 0.4933-0.4975, depending on the $CaCO_3$ content of magnesite (average calcium carbonate content at 2.59% versus to 92.34% average magnesium carbonate content). The IEF is very close to the one estimated in the recent years, therefore the reporting is considered complete.

In the same time, using the quantity of magnesia produced, the emission factor of tn of CO_2/tn of magnesia produced has been estimated. This EF oscillates between 0.97-1.17, while the average is 1.05 t CO_2/t magnesia, and is considered a country specific one, as it has been

estimated using information of the chemical analysis of the ore. This EF was used for the calculation of years prior to 1999, as it is described further below.

Years 1999-2004: for that period the quantities of magnesite used in the kilns and the production of magnesia (both types as a total) has been provided by the single plant operating in Greece. Emissions have been estimated using the quantity of magnesite produced and the average carbonate contents of the years 2005-2008 in order to ensure the consistency between the time-series.

Years 1990-1998: As regards to the years previous to 1999, the produced quantities of magnesia have been provided by the Hellenic Statistical Authority, since there were more than one plant operating in Greece in the period 1990-1999. Emissions have been calculated using the average EF of 1.10 t CO_2/t magnesia that has been estimated from the years 2005-2008, in order to ensure time-series consistency. In order to report activity data in the form of magnesite consumption (instead of magnesia), as it is required by the CRT reporting and since emissions from magnesia production are only a part of the emissions from Limestone and Dolomite Use, for the years 1990-1998, the IEF of 0.4951 t CO_2/t magnesite (mean value of the detailed estimations of 2005-2008), has been used backwards.

It should be noted that, provided that data on the fraction calcination achieved are not available, it has been assumed that the fraction calcination is equal to 1.

- **Primary aluminium production**: Data on primary aluminium production are plant specific and confidential (there is only one plant in Greece). The emission factor used is 0.44, whereas the single carbonate estimated is $CaCO_3$. Plant specific data on limestone consumption cover the years 1990 and 1998 – 2015. The specific limestone consumption has been used for filling in missing data. In 2012 the limestone consumption amounts to 53.66 kt of $CaCO_3$ eq, while in 2011 it was 117.04 kt of $CaCO_3$ eq. Since 2013 the limestone consumption was zeroed as the limestone kiln ceased its operation and after personal communication with the plant, we were informed that any need in raw materials was covered through imports.
- **SO_2 scrubbing**: The operation of flue gas desulphurization systems in Greece started in 2000. The estimation of emissions is based on data collected during the formulation of the NAP for the period 2000 – 2003 and concern limestone consumption in two power plants. Limestone consumption for 2004 was estimated assuming that the specific limestone consumption per electricity produced in those two power plants is kept constant at 2003 levels. For years 2005-present data from verified installation ETS reports were used. The emission factor used (0.44 t CO2 / t limestone) derives from the stoichiometry of the reaction.
- **Mineral wool**: Mineral wool is an insulating material industrially produced through melting and fiberizing of ores. Emissions occur during the production where decomposition of carbonate (amphibolites, bauxite and CaO) and consumption of graphite electrodes occur. The production of mineral wool by the only plant operating in Greece started in 2002 (Line 1). In 2008 a second line (Line 2) started its operation at the same plant. Activity data and CO_2 emission for the years 2002-2012 were provided by the sole plant operating in Greece after personal communication of the inventory team. The limestone consumption for the years prior

to 2013 were calculated based on a default EF equal to 0.44 t CO2 / t limestone. Since 2013 AD and CO_2 emission are provided by the EU-ETS reports.

Figure 4.6 summarizes the contribution of the above-mentioned sub-categories in the Other Process Uses of Carbonates category, depicting the annual variations in CO_2 emissions.

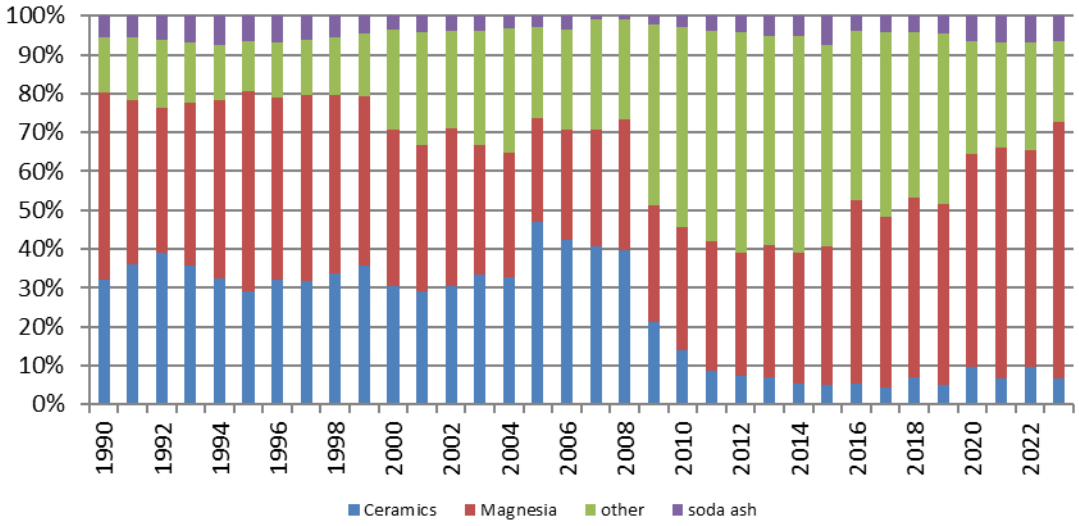


Figure 4.6 ***Contribution of each subcategory of the Other Process Uses of Carbonates category for the period 1990 – 2023***

4.5.3 Uncertainties and time-series consistency

In general, the uncertainty associated with the emission factor for this source category is relatively low, as the emission factor is the stoichiometric ratio reflecting the amount of CO_2 released upon calcination of the carbonate. In practice, there are uncertainties, in part due to variations in the chemical composition of the limestone and other carbonates and therefore the value of 5% is being used to account for the EF uncertainty.

Assuming that carbonate consumption is allocated to the appropriate consuming sectors/industries, the uncertainty concerning the activity data is associated with the weighing or proportioning of the carbonates and with the overall chemical analysis pertaining to carbonate content and identity. Therefore the uncertainty value associated with the activity data is estimated at 10%. This uncertainty value also accounts for the assumption of 100% calcination.

The time-series consistency is ensured by the fact that the applied methodology is consistent with the IPCC Guidelines and remains the same throughout the time-series. In addition, the abrupt increase of emissions in 2005 was investigated (***Figure 4.7***). Although slight corrections have been made for years 2005, 2006 and 2007 to accurately depict reported data, the peak remains and is attributed to the lower consumption of carbonates in 2006 with reference to 2005, mainly in the ceramic plants. From 2008 a severe decrease in emissions occurred due to the economic recession

and the closure of over half of the ceramic industries in Greece. In particular in 2015 the respective decrease in emissions in the Ceramics Sector is -94.19% compared to 2005. However, in 2019 there is a slight decrease in emissions of about 1.52% compared to 2018.

In particular, regarding SO_2 scrubbing, since 2009-2011 an increase in emissions occurred, determining the trend in emissions for the whole subcategory. The following years until 2019 fluctuation in emissions were reported always in accordance with the verified ETS reports. In 2020, however, a major decrease (-61.56%) was reported as one of the major power plants in Greece ceased its operation, resulting emissions decrease.

In addition, emissions from magnesia production, which is the second dominant industry of this sub-cateogory, were continuously increasing since 2009. However, in 2020, a severe decrease of -41.21% was reported, attributed to the cease of one out of the 3 plants operating in Greece during the recent years.

Finally, in 2023 CO2 emission decreased by -11.10% compared to 2022.

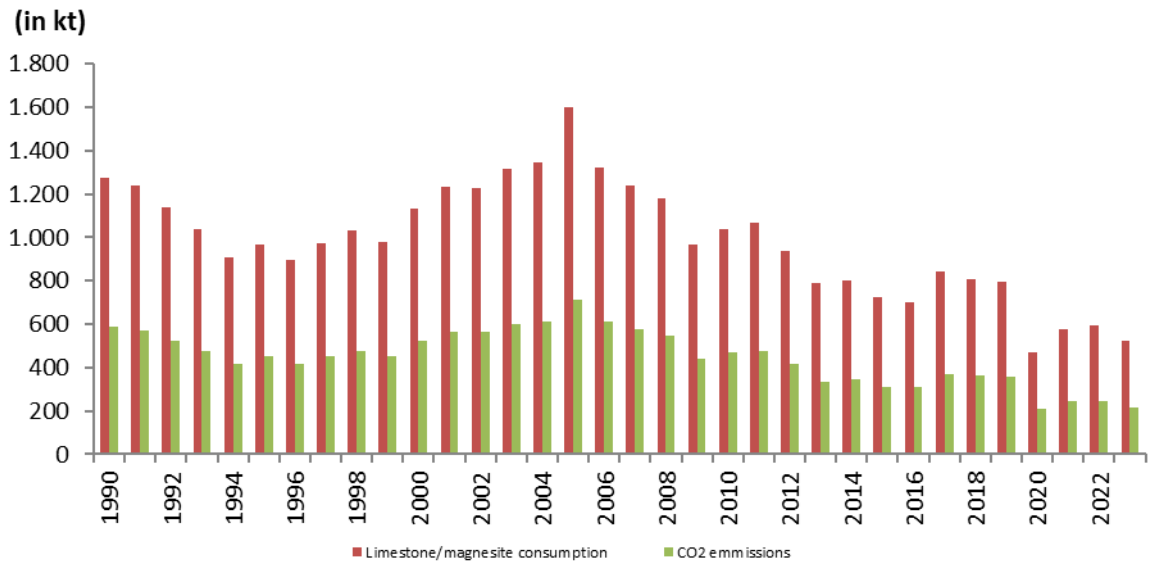


Figure 4.7 ***CO_2 emissions (in kt) and Limestone/ magnesite consumption (in kt) from Other Process Uses of Carbonates for the period 1990 – 2023***

In ***Table 4.10*** emission factors for each subcategory are presented. The variation of the EFs, in addition to the percentage of contribution of each subcategory every year, is the main reason for the fluctuations of the IEF throughout the timeseries. Therefore, with reference to the emission factor used in the most recent years (2005-present), the deviation from the stoichiometric one is attributed to the fact that in the years that magnesia production is higher, as the IEF equal to 0.495 t CO_2/t magnesite is taken into account, the overall resulting IEF is higher than 0.44.

Table 4.10 Emission factors range for the Limestone and dolomite use subcategories over the years 1999-2023

Subcategory	EF Range (Years 1999-present)
Ceramics	0.413-0.470
Soda ash use	0.415
Primary aluminium Production	0.434-0.44
SO_2 scrubbing	0.44
Magnesia Production	≈0.48
Mineral wool Production	≈0.44

4.5.4 Source specific QA/QC and verification

The verification of the activity data by alternative sources is generally hard to be performed, given the complexity and the divergence of the manufacturing plants. In addition, although the activity data used are plant specific, the uncertainty of the estimation of emissions from limestone and dolomite use is increased by the fact that in some cases there is no production data available by the ElStat (i.e. ceramics production) in a way that it is really difficult to estimate emissions in different Tiers. It should be noted however that all the reports made available in the ETS context have been additionally checked by external accredited verifiers, as defined by the Greek ETS system, and also that whenever available data are being cross-checked with information from different sources (i.e. in the case of magnesia production).

4.5.5 Recalculations

No recalculations have been performed during this submission.

4.5.6 Planned improvements

No planned improvements reported.

4.6 Ammonia production (CRT Source Category 2.B.1)

4.6.1 Description

Carbon dioxide is emitted as an intermediate product during the production of anhydrous ammonia. Catalytic steam reforming of the fuel used as feedstock (carbon source) takes place during the production process, leading to the release of CO_2 emissions.

Up to 1999 there were two ammonia plants in Greece. The first one (Plant A) has been operating since 1990, with an interruption between the years 1994-1997. It should be mentioned that imported Natural Gas was introduced to the Greek energy system by the Public Gas Company (DEPA) in 1996 and that till 1996 the NG consumption in Greece corresponds to small amounts of domestic NG explored by the company Kavala Oil. As a result, the plant has been using natural

gas, provided by the Public Gas Company SA (DEPA) since 1998 while in the years 1990-1993 natural gas has been provided to the plant by the Kavala Oil Corporation.

The other plant (Plant B) has been operating since 1990 and up to 1999 with intervals. According to information already provided in NIR 2010, it used lignite as feedstock until 1991, and liquid fuels until its closure in 1999. In absence of gas consumption data, only CO_2 emissions from Plant A have been estimated. CO_2 emissions in IP refer to emissions from natural gas (years 1990-1993 and 1998-2015), whereas emissions from the other fuels used, namely liquid fuels, (years 1990-1993 and 1995-1998) are included in the energy sector. CO_2 emissions from lignite used during years 1990-1991 had been reallocated during 2014 submission from the Energy Sector (1A2c) into the Industrial Processes Sector. It should also be mentioned that both plants were closed during year 1994.

Ammonia production constitutes a key category by trend assessment. CO_2 emissions in 2023 representing 1.62% of GHG emissions from *Industrial processes*.

4.6.2 Methodology

The methodology used for the estimation of CO_2 emissions is based on the following equation:

$$E = TRF \cdot CCF \cdot COF \cdot 44/12$$

where *E* stands for CO_2 emissions, *TRF* is the total fuel requirement (GJ of natural gas), *CCF* is the carbon content factor, *COF* is the carbon oxidation factor and 44/12 is the stoichiometric ratio of carbon dioxide to carbon.

The country specific carbon content of fuel (natural gas) is estimated as described:

- The CC of domestic NG is 16.20 tC/TJ (it is the mean value of CC of NG from the different reservoirs that NG was extracted). This value has been used for years 1990-1993.
- The CC of imported NG is calculated based on the chemical composition data of natural gas provided by DESFA (Hellenic Gas Transmission System Operator S.A.), as described in 3.2.4.4.2 of the present NIR. It should be noted that there is no urea production in Greece. The above mentioned plant only markets urea as a result of import.
- The carbon oxidation factor is assumed to be 100%.

The CC of imported NG per year is presented in ***Table 4.11***.

Table 4.11 Carbon Content of imported NG for years 1998-2023

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CC (tC/TJ)	15.03	15.03	15.03	15.10	15.10	15.11	15.11	15.10	15.10	15.10	15.12
Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019

CC (tC/TJ)	15.14	15.16	15.07	15.16	15.10	15.10	15.24	15.23	15.19	15.24	15.22
Year	2020	2021	2022	2023							
CC (tC/TJ)	15.22	15.11	15.15	15.19							

Activity data concerning fuel consumption for the years 1998-2009 have been provided by the plant using natural gas and by DEPA. Data for 2010 – 2012 are plant specific and provided by the sole plant operating in Greece, while since 2013 data are provided to the inventory team under the EU ETS system. National ammonia production for the whole time-series has been provided by the ElStat and for the years 1998-2015 by the one plant still operating in Greece. All the activity data and the estimated emissions are presented in Table 4.12.

Table 4.12 Ammonia production, natural gas consumption and CO2 emissions for the period 1990 – 2023

Year	Ammonia Production (kt)	NG consumption (TJ)	CO_2 emissions (kt)
1990	313.03	4046.40	652.04
1991	255.61	3866.40	620.50
1992	167.94	3676.50	218.32
1993	69.78	2369.70	140.72
1994	0.00	0.00	0.00
1995	96.98	IE	IE
1996	133.91	IE	IE
1997	122.16	IE	IE
1998	244.76	3221.06	177.48
1999	233.33	5152.26	283.96
2000	147.48	5005.86	275.90
2001	68.70	2451.96	135.77
2002	94.14	2815.91	155.94
2003	150.18	4918.21	272.40
2004	159.92	5224.00	289.46
2005	143.88	4755.67	263.30
2006	160.90	5284.66	292.59
2007	165.77	5401.55	299.16
2008	125.91	4155.71	230.37
2009	102.86	3379.32	187.61
2010	159.00	4870.54	270.76
2011	157.59	4728.78	262.51
2012	106.69	3214.67	178.73
2013	128.14	3831.36	212.13
2014	144.56	4359.26	241.31
2015	145.21	4302.90	240.51
2016	91.40	2722.24	151.98

2017	162.44	4806.81	267.71
2018	148.16	4381.66	244.82
2019	135.05	4,005.57	223.60
2020	115.79	3518.57	196.30
2021	114.68	3540.11	196.19
2022	156.70	4700.46	261.14
2023	90.16	2.649,49	147.55

4.6.3 Uncertainty and time-series consistency

Although the data are plant-specific, a level of uncertainty originates from the fact that the gaseous inputs are generally more uncertain that the liquid or solids inputs. Therefore, the EF uncertainty value used has been evaluated at 6%, based on a country-specific estimation. As regards to the activity data, in general the accounted uncertainty is considered quite lower (3%), on the basis that data are plant-specific and have been quality checked by the input of different sources.

The emissions over the time-series are characterised by intense fluctuations. This is due to the fact that the operation of both plants was quite unstable, while part of the emissions is still accounted in the energy sector, due to lack of information on the liquid fuels used, since the relevant plant has ceased operation since 1999. More specifically, the emissions estimation that refer in liquid fuels for years 1993-1999 are included in the category 1.A.2.c for Chemicals of Manufacturing Industries and Constructions of the Energy sector, under “Liquid Fuels”.

Emissions show a minimum in 2001 (135.77 kt CO_2) and a maximum in 2007 (299.16kt CO_2). As described above, from 1990 to 1993 the ammonia production refers to the national production from both plants, whereas the emissions have resulted from the operation of plant A alone. The fluctuation noticed in these years is therefore attributed to the different percentage of each industry’s contribution to total ammonia production. The high EF during the years 1990-1991 can be attributed to the reallocation of emissions from lignite, while the low IEF for years 1992, 1998 and 1999 can be attributed to the fact that the emissions refer to one industry, while the production to both. This changes in 2000 (final closure of plant B) and as a result the IEF is close to the average value of the next years (1.781 kt CO2/kt NH3). Between 2000 and 2001 NG consumption and the ammonia production are both reduced to half (51% and 53% accordingly). The interannual change of the IEF is attributed to the carbon content of the imported natural gas that changes from 15.03% to 15.10% from 2000 to 2001, respectively.

However, for recent years the IEF is quite stable and any minor fluctuations can be attributed to the variation of the carbon content of the NG used (***Table 4.11***). Any other change of the IEF is attributed to the CC and consumption of natural gas. It should be noted that in 2023, the plant changed ownership, marking a significant turning point after years of operational instability.

4.6.4 Source-specific QA/QC and verification

The source-specific QA/QC procedures include the comparison of emissions calculated with different tiers. The default EF reported in the 2006 IPCC Guidelines is about 1.7 t CO_2/t ammonia produced.

However, based on the European average values for specific energy consumption (Mix of modern and older plants), reported also in the 2006 IPCC guidelines, the default EF is 2.1 t CO_2/t ammonia produced. The estimated IEF is in the range of reported emission factors, as it can be clearly seen in ***Figure 4.8***.

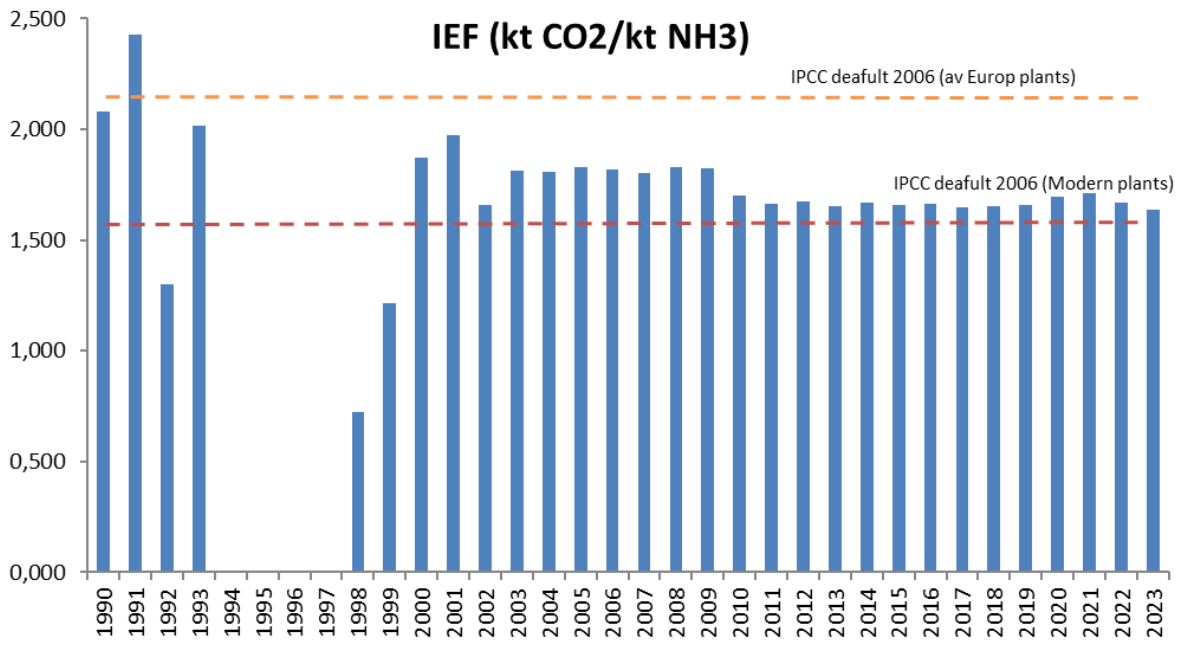


Figure 4.8 Fluctuation of the IEF in the inventory years

Additional QC checks include the gathering of data from different sources. This is being performed in two ways:

1. Ammonia production: the plant-specific production data are cross-checked with alternative sources. These sources include ElStat (Prodcom department, confidential data) and the Ministry of Development and Investments have been used, whenever available.
2. NG Consumption: The natural gas quantity used by the one plant operating in Greece is gathered by both the NG provider (DEPA) and by the sole plant producing ammonia in the recent years through the EU ETS reports. In addition, for years 1990-1993 data have been received by Kavala Oil. In order to ensure time-series consistency and also consistency with the energy sector, DEPA and national statistics are being used, while the ammonia's producer information is gathered for additional QC use. In general, there is a difference of 5% between the two values, which can be considered quite stable and is attributed to the general uncertainty of the gaseous fuels input.

4.6.5 Recalculations

No recalculations have been performed in this submission.

4.6.6 Planned improvements

There are no planned improvements as the current submission can be considered satisfactory.

4.7 Nitric acid production (CRT Source Category 2.B.2)

4.7.1 Description

Emissions of nitrous oxide are generated during nitric acid production and specifically from the process of catalytic oxidation of ammonia under high temperature.

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

Nitric acid production (N_2O emissions) is a key category by trend assessment. Nitrous oxide emissions from nitric acid production in 2023 (***Table 4.13***), account for 0.08% of total GHG emissions from *Industrial Processes*.

4.7.2 Methodology

N_2O emissions from nitric acid production are estimated according based on Tier 3 methodology and are based on real measurement data. The CO_2 emissions deriving from these measurements are provided to the inventory team through the ETS verified reports.

The following are noted in relation to the application of the above equation:

- For the years prior to 2013 the emission factor used is the average of the default values suggested by the IPCC Guidelines for units operating under medium pressure (7 kg N_2O / t HNO_3). The inventory team has communicated with the relevant plant and the EF used is according to the operation conditions reported by the plant. (The methodology used for the production of nitric acid is Dual Pressure. Ammonia is catalytically burned in presence of air at 4 bars.).
- Nitric acid production data derive from ElStat and the individual industrial units for 1990-2012. Actually, since 2006 there is only one unit producing nitric acid in Greece therefore, data are received directly by the unit.
- The emissions concerning nitric acid production for the years since 2013 are provided by the ETS reports.

- Since 1/1/2013 a catalytic conversion system of N_2O to nitrogen operates in the nitric acid plant, as reported by the sole plant operating in Greece, therefore a CS methodology, equivalent to the IPCC Tier 3 methodology, is being used.
- The abatement system used by the Greek installations for reduction of NO_x emissions is the absorption tower.

Table 4.13 Nitric acid production (in kt) and N_2O emissions (in kt) for the period 1990 – 2023

Year	HNO_3 production (kt)	N_2O emissions (kt)
1990	511.08	3.58
1991	421.38	2.95
1992	440.65	3.08
1993	418.45	2.93
1994	406.84	2.85
1995	404.84	2.83
1996	462.31	3.24
1997	406.04	2.84
1998	334.13	2.34
1999	346.99	2.43
2000	355.33	2.49
2001	298.65	2.09
2002	287.53	2.01
2003	265.39	1.86
2004	252.32	1.77
2005	251.52	1.76
2006	204.01	1.43
2007	202.55	1.42
2008	194.61	1.36
2009	169.32	1.19
2010	197.42	1.38
2011	219.11	1.53
2012	141.48	0.99
2013	173.93	0.07
2014	182.13	0.09
2015	198.52	0.07
2016	115.77	0.05
2017	190.05	0.07
2018	190.18	0.08
2019	180.03	0.07
2020	189.01	0.06

2021	175.99	0.02
2022	195.40	0.03
2023	176.32	0.02

4.7.3 Uncertainty and time-series consistency

The uncertainty arisen by the currently implemented methodology has been considered equal to 3% for the emission factor and 2% for the production data used. As regards to the AD accuracy, the uncertainty value accounts mainly from the uncertainty of the produced nitric acid quantity.

The time-series consistency of emissions is assured by applying consistent methodologies and verified activity data in line with IPCC guidelines. In the case of nitric acid production, the default methodology has been used for the years prior to 2013, while a country specific methodology (Tier 3) is used since 2013.

The trend of the time-series can be seen in ***Figure 4.9***. As it can be seen from this Figure, the trend is generally decreasing, apart from 2010-2011 those emissions appear to be increased in relation to 2009. This however was counterbalanced by the 2012 decrease in emission, which appeared to be even lower than 2009 (-16.44% since 2009 and -35.43% since 2011). Since the same emission factor has been used for all the years of the time series, according to the information provided by the plant, the changes of the emissions indicate the general change of the production level.

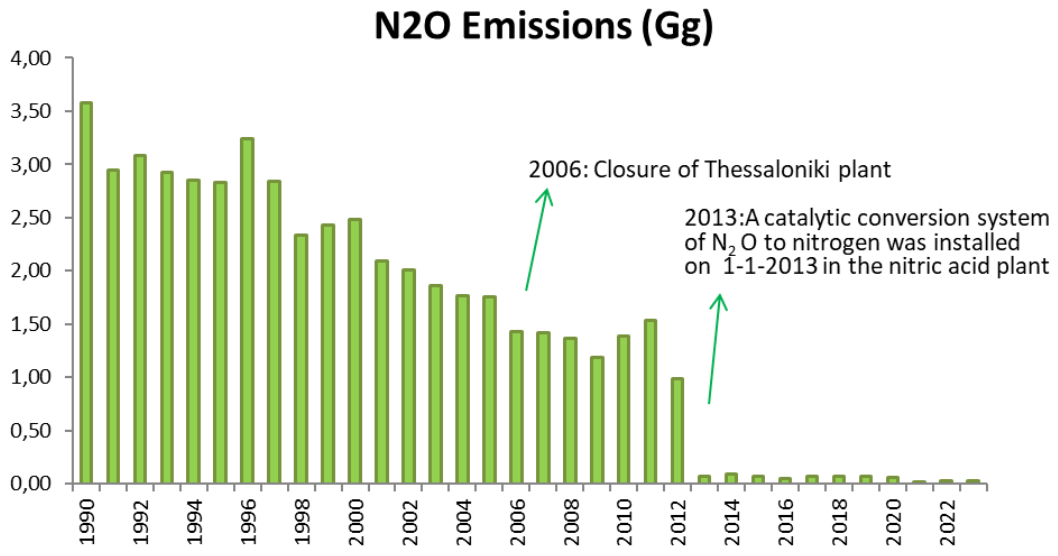


Figure 4.9 ***N_2O emissions (in kt) from Nitric Acid Production for the period 1990 – 2023***

In 2013-present a severe decrease in emission is noticed due to the installation of a catalytic conversion system of N_2O to nitrogen in the nitric acid plant.

4.7.4 Source-specific QA/QC and verification

According to the QA/QC procedures, all the information received by the plants is archived in the Input File of the Greek Inventory system. Additionally, the plant specific data are being cross-checked with confidential data collected by the ElStat, depending on data availability.

In specific, the main source for the estimation of emissions is the data received directly by the one plant operating in Greece. Additional Quality Control Checks make use of confidential information provided by the ElStat, regarding HNO_3 production. Although PRODCOM data are provided each year, they may not be finalized by the annual submission of the inventory. However, even in that case the Service unofficially provides the Inventory Team with the provisional data, following the QC procedures of the Service. In that case the final QC checks may take place in the following year, and the respective results are presented in the next submission. Since 2013 the data are acquired by the ETS reports that are also verified by the accredited verifiers of the Greek Emissions Trading System. Until 2012, the estimate was the best available according to the data provided by the sole plant operating in Greece. In addition, for the years prior to 2013 the emission factor used is stable 7 kgN_2O / t HNO_3, equal to the average of the default values suggested by the IPCC Guidelines (IPCC, 2006) for units operating under medium pressure, according to the information provided by the plant.

4.7.5 Recalculations

No recalculations have been performed during this submission.

4.7.6 Planned improvements

After the installation of an abatement technique for the recovery of N_2O emissions no improvements are planned as the current submission can be considered satisfactory.

4.8 Petrochemical and Carbon Black Production (CRT Source Category 2.B.8)

4.8.1 Description

CO_2, CH_4 and NMVOC emissions from the production of ethylene and 1,2 dichloro-ethane, as well as NMVOC emissions from the production of polyvinylchloride and polystyrene are included in this category.

CO_2 and CH_4 emissions deriving from the Petrochemical and Carbon Black Production (namely ethylene and 1,2 dichloro-ethane production) ceased in 2000, due to the cease of ethylene and 1,2 dichloro-ethane production in Greece in 1998 and 2000, respectively. With regards to CH_4 emissions, their contribution to total GHG emissions from *Industrial Processes* is less than 0.01%

for the period 1990 – 2000. ***Table 4.13*** presents the emissions from Petrochemical and Carbon Black Production.

Table 4.14 Emissions from Petrochemical and Carbon Black Production (in kt) for the period 1990 – 2001

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
CO_2 emissions	28.61	29.15	29.68	29.30	30.43	32.03	33.38	33.02	31.23	8.52	6.06	NO
CH_4 emissions	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.02	0.01	NO

4.8.2 Methodology

<u>CO_2 Emissions</u>

CO_2 emissions from the production of ethylene and 1,2 dichloro-ethane are estimated according to the equation:

$$E_{CO_2} = PP \cdot EF \cdot GAF/100$$

where E_{CO2} = are the CO_2 emissions from production of petrochemical (t), *Pp*is the annual production of petrochemical (t), *EF* is the CO_2 emission factor for petrochemical (t CO_2/t product produced) and *GAF*is the Geographic Adjustment Factor (equal to 110% for Eastern Europe for Tier 1 CO_2 emission factors).

Default emission factors (IPCC Guidelines) are used. Wherever available the updated 2006 IPCC guideline Efs are being used. With regards to CO_2 emissions the default Efs were used in both the cases of ethylene and Ethylene dichloride according to the 2006 IPCC Guidelines. Activity data (production of ethylene and 1,2 dichloro-ethane) are confidential and provided by ElStat, until the production has ceased in 1998 and 2000, respectively.

<u>CH_4 Emissions</u>

CH_4 emissions from the production of ethylene and 1,2 dichloro-ethane are estimated according to the equation:

(Emissions) = (Production) * (Emission factor)

Default emission factors (IPCC Guidelines) are used. With regards to CH_4 emissions the default EF used in the case of ethylene production is obtained from the 2006 IPCC Guidelines. Concerning the CH_4 emissions' EF for ,2 dichloro-ethane the default value from 1996 Guidelines is the only one available. Activity data (production of ethylene and 1,2 dichloro-ethane) are confidential and provided by ElStat,until the production has ceased in 1998 and 2000, respectively.

<u>NMVOC Emissions</u>

Emission factors used for ethylene, 1,2 dichloro-ethane, PVC and Polystyrene are the default ones. The EMEP 2013 Guidelines are used as the IPCC Guidelines do not provide default Efs for NMVOC emissions. The available data cover the period 1990 – 2007 for PVC and Polystyrene, whereas the ethylene and 1,2 dichloro-ethane production cover the years from 1990 to 1998 and 2000, respectively.

4.8.3 Uncertainty and time-series consistency

CO_2 emissions from the ethylene and dichloroethane production have been included for the years 1990-2000. The Tier 1 methodology and the default EFs of the 2006 IPCC guidelines have been used for the calculation of CO_2 emissions, whereas the production data are provided by the ElStat.

To account for both uncertainties type the value of 5% has been considered.

With regards to methane emissions, time-series consistency is ensured by the fact that the same EF and methodology has been used for all the inventory years. In particular, the EF for the CH_4 emissions has been updated from 1t/kt ethylene to 3t/kt ethylene according to the 2006 IPCC guidelines.

The time-series show an important decrease from year 1998 to 1999 due to the cease of the ethylene production. After 2000 both emissions have been zeroed, as a result of the production cease.

4.8.4 Recalculations

No recalculation has been performed in this submission.

4.8.5 Planned improvements

The current submission can be considered satisfactory.

4.9 Fluorochemical Production (CRT Source Category 2.B.9)

4.9.1 Description

HFC-23 is generated as a by-product during the manufacture of HCFC-22 and emitted through the plant condenser vent.

HFC-23 emissions from HCFC-22 manufacture used to be a key category by level and trend in the past years. However, the HCFC-22 production has ceased in January 2006 and emissions do not occur ever since.

HFC-23 emissions are shown in Table 4.15.

Table 4.15 HFC-23 emissions (in kt CO_2 eq) from HCFC-22 production for the period 1990 – 2022

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
HFC-23	1182.82	1400.08	1149.07	2023.34	2711.95	4114.99	4738.96	5009.50	5515.07	6353.94	4724.75
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
HFC-23	4024.42	4040.99	3366.11	3226.40	2729.12	NO	NO	NO	NO	NO	NO
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFC-23	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Methodology

According to the 2006 IPCC Guidelines, the analytical methodology (Tier 2) should have been applied for the calculation of HFC-23 emissions from HCFC-22 production, as it used to be a key source. This methodology is based on the collection and elaboration of onsite measurement data. However, due to the lack of such data, calculation of emissions has based on production statistics and a reference emission factor. It should be noticed that data on the production of HCFC-22 are confidential and therefore are not presented in the current report. The reference emission factor used is suggested by the 2006 IPCC Guidelines.

4.9.2 Uncertainty and time-series consistency

The estimated uncertainty is estimated at 50% for both activity data and emission factor, as suggested in the 2006 IPCC Guidelines for Tier 1 methodology.

The implemented methodology is in line with the IPCC Guidelines, while no changes or refinements are to be expected in the current category. The estimation methodology used is the same for the whole time-series.

4.9.3 Source-specific QA/QC and verification

In order to ensure the quality control, all the collected data regarding emissions are kept in the Input file of the inventory system.

4.9.4 Recalculations

No recalculations have been performed.

4.9.5 Planned improvements

The current submission can be considered satisfactory.

4.10 Other Chemical Production (CRT Source Category 2.B.10)

CO_2 emissions from Hydrogen production deriving from natural gas (NG) are included in this category. In 2011 submission these emissions were included in the Energy Sector, but in 2012 they have been reallocated in the IP sector, in line with the ERT recommendations.

Other Chemical Production (CO_2 emissions) is a key category by level and trend assessment. The contribution of CO_2 emissions from Hydrogen Production account for 5.14% of the *Industrial Processes* emissions. ***Table 4.16*** presents the emissions from Hydrogen production.

Table 4.16 Emissions from Hydrogen production (in kt) for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO_2 emissions	NO	NO	NO	NO	NO	NO	NO	83.17	173.51	60.85	NO	NO	9.75	14.21
Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions	15.06	33.62	21.34	18.78	107.69	265.65	362.13	321.88	323.29	304.78	328.08	254.53	309.95	536.90
Year	2018	2019	2020	2021	2022	2023								
CO_2 emissions	706.37	654.14	649.23	483.23	49.34	301.13								

4.10.1 Methodology

CO_2 emissions for H_2 production are estimated on the basis of the natural gas consumed for the process. Hydrogen production emissions refer to years after 1997, as natural gas consumption refers to the imported Natural Gas that was introduced in1996 to the Greek energy system Data are provided by the Public Gas Company (DEPA) for the whole time-series and by the verified EU ETS reports of the refineries for years 2005-present. In ***Table 4.17*** the estimation parameters can be viewed. It should be mentioned that the activity data reported in the CRT Reporter refer to the quantity of natural gas consumed in TJ, although the CRT reported unit is kt (please also see the relevant comment). This is due to the unavailability of reporting in TJ units in the *Industrial Processes* Sector. The reporting in kt equivalent could have been performed if the NCV was available, however the relative consumption in the energy balance is given directly in energy units and therefore there is no such information to be used accordingly. At this point, it should be mentioned that the associated emissions from hydrogen production from liquid fuels are reported under Energy CRT category 1.A.1.b (please also refer to Section 3.2.3).

Table 4.17 Parameters for the Estimation of CO2 Emissions from Hydrogen Production (1997-2023).

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
NG Consumption (TJ)	1509.38	3149.11	1104.06	0.00	0.00	176.05	256.52	271.72	607.30	385.44	339.15
CC (t C/TJ)	15.03	15.03	15.03	15.03	15.10	15.10	15.11	15.11	15.10	15.10	15.10
EF (t CO2/TJ) (Oxid Fact=100%)	55.10	55.10	55.11	55.12	55.37	55.38	55.39	55.41	55.37	55.37	55.38
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
NG Consumption (TJ)	1942.69	4785.09	6459.80	5745.16	5766.52	5464.98	5863.78	4563.37	5540.82	9579.03	12642.09
CC (t C/TJ)	15.12	15.14	15.29	15.28	15.29	15.21	15.26	15.21	15.26	15.29	15.24
EF (t CO2/TJ) (Oxid Fact=100%)	55.43	55.52	56.06	56.03	56.06	55.77	55.95	55.78	55.94	56.05	55.87
Year	2019	2020	2021	2022	2023						
NG Consumption (TJ)	11718.44	11636.86	8680.29	885.140	5.416,65						
CC (t C/TJ)	15.22	15.22	15.18	15.20	15,16						
EF (t CO2/TJ) (Oxid Fact=100%)	55.82	55.79	55.67	55.74	55,59						

It should be noted that the CC values used in table 4.11 (Ammonia production source category) are the values based on the country specific data (CC), which are calculated as described in Chapter 3 – Energy Sector. On the other hand the CC values used for H2 production are based on the plant specific data provided (through EU ETS reports), and are used as they led to higher accuracy.

Please also refer to section 3.2.3 (Energy sector), where the consistent allocation of emissions between IPPU and energy sectors, throughout the time-series, is explained.

4.10.2 Uncertainty and time-series consistency

The uncertainty of the activity data and the EF for the CO_2 emissions estimation is 3% (for both values), on the basis that the relevant information is plant specific and provided by the verified reports.

The time-series of the CO_2 emissions show important fluctuations. Hydrogen production has started in 1997, in a way that the natural gas consumption refers to the imported Natural Gas that was introduced to the Greek energy system by the Public Gas Company (DEPA) in 1996. In the recent years emissions experience a strong increase that was very intense for 2010, due to the important increase of both carbon content and natural gas consumption in the activity data (***Figure 4.10***). However, in 2012 the CO_2 emissions were reported stable compared to 2011, which is connected to the similar NG consumption, as carbon content was reported to be also stable comparing to 2011. In 2014 the CO_2 emissions appeared a increase by 7.64% since 2013, followed by a decrease 22.42% in 2015. In 2016 an increase by 21.77% appeared compared to 2016, while in 2017 the increase was 73.22% compared to previous year according to the ETS reports. Emissions in 2018 increased by 31.56% compared to 2017 and decreased by 7.39% between 2018 and 2019. Emissions in 2020 decreased by 0.75% compared to 2019 followed by an additional decrease of -25.5 % in 2021. In 2022 an abrupt decrease in emissions of -89% was reported attributed to the fluctuating energy prices (with wholesale prices of natural gas and electricity reaching historically high levels during 2022-2023), especially following the aggressive war

against Ukraine, which exposed the EU's dependence on energy imports. In 2023 this decrease was counter balanced by a huge increase of 510%, but still not being able to reach the levels of 2021.

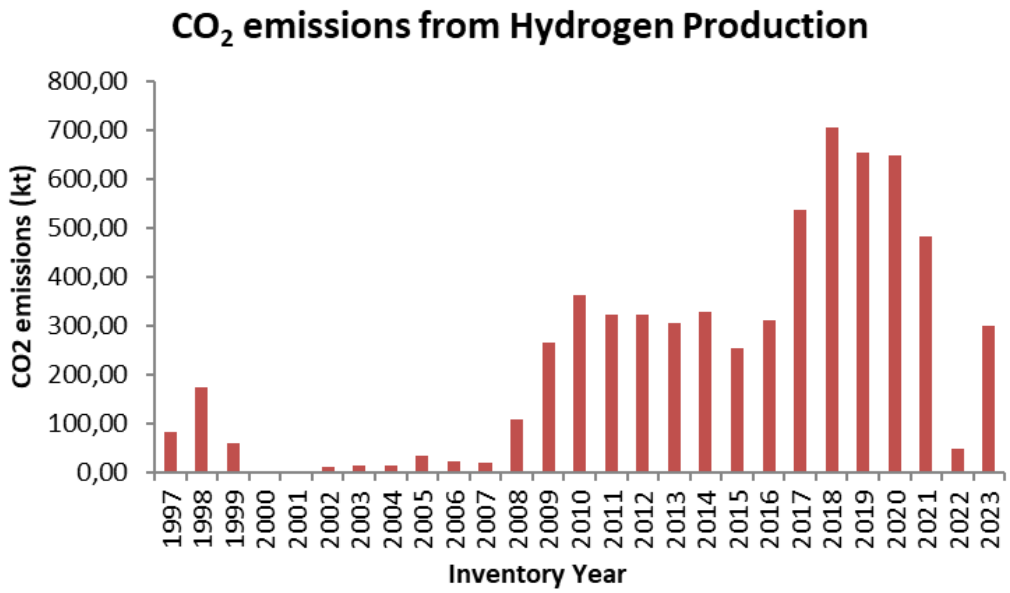


Figure 4.10 CO_2 emissions (in kt) from Hydrogen Production for the period 1990 – 2023

4.10.3 Source-specific QA/QC and verification

For years where data from both DEPA and the EU ETS are available, namely years 2005-present, the consumed quantities of natural gas are being cross-checked. In addition, the ETS reports used in the estimation of CO_2 emissions from Hydrogen Production are verified by the accredited verifiers of the Greek Emissions Trading System.

4.10.4 Recalculations

No recalculation was performed during this submission, which is in line with the reviewers comments.

4.10.5 Planned improvements

The current submission can be considered satisfactory.

4.11 Iron and steel production (CRT Source Category 2.C.1)

4.11.1 Description

Steel production in Greece is based on the use of electric arc furnaces (EAF). There are no integrated iron and steel plants for primary production as no units for primary production of iron exist, but there are several iron and steel foundries. Emissions from Iron and Steel do not constitute a key category.

Carbon dioxide emissions from steel production in 2023 (***Table 4.18***) accounted for 0.71% of total GHG emissions from *Industrial production*.

Table 4.18 Steel production, CO_2 emissions and CH_4 emissions (in kt) for the period 1990 – 2023

Year	Steel production (kt)	CO_2 Emissions (kt)	CH_4 Emissions (kt)
1990	999.10	104.89	0.01
1991	980.00	104.15	0.01
1992	924.00	98.85	0.01
1993	980.00	101.87	0.01
1994	848.00	87.39	0.01
1995	939.00	95.51	0.01
1996	809.82	83.64	0.01
1997	1015.67	103.42	0.01
1998	1108.29	113.19	0.01
1999	951.53	98.67	0.01
2000	1104.78	112.68	0.01
2001	1281.51	129.51	0.01
2002	1839.80	181.73	0.02
2003	1700.90	170.64	0.02
2004	1966.24	195.32	0.02
2005	2296.40	229.51	0.02
2006	2415.80	229.61	0.02
2007	2554.52	237.14	0.03
2008	2468.10	215.75	0.02
2009	1999.35	142.82	0.02
2010	1824.14	122.84	0.02
2011	1934.32	133.85	0.02
2012	1247.10	86.82	0.01
2013	1030.00	69.11	0.01
2014	1022.00	70.33	0.01

2015	910.00	61.36	0.01
2016	1158.00	73.53	0.01
2017	1359.00	80.73	0.02
2018	1467.00	91.16	0.01
2019	1349.87	81.45	0.01
2020	1323.45	74.08	0.01
2021	1606.29	84.09	0.02
2022	1544.18	81.87	0.02
2023	1134.17	65.15	0.01

Especially in years 1990-2000 there was an increasing trend of the production. It should be noted, however, that emissions in 2009-2023 have significantly decreased from 2008, as a result of the decreased economic activity of the sector.

Methane emissions remain at low levels and in 2023 and account for 0.003% of the emissions from *Industrial Processes*.

4.11.2 Methodology

The methodology used for the estimation of carbon dioxide emissions is based on tracked carbon oxidation throughout the production processes in electric arc furnace operation. For the estimation the following equation has been used:

$$E_{CO2} = (SC+AN+C+GR+EL+LC-SLB-SLG-D-CL)*44/12$$

where SC=quantity of scrap*carbon content of scrap, AN=quantity of anthracite*carbon content of anthracite, C=quantity of coke*carbon content of coke, GR=quantity of graphite*carbon content of graphite, EL=quantity of electrodes*carbon content of electrodes, LC=lime consumption* carbon content, SLB=quantity of slab*carbon content of slab, SLG=quantity of furnace and vat slug*carbon content of slug, D=quantity of dust in the dust filter*carbon content of dust and CL=quantity of calamine*carbon content of calamine.

In relation to the estimation of CO_2 emissions from iron and steel production, it should be noted that:

- Activity data for 2005-present are plant specific and are based on the verified reports under the EU ETS context.
- According to information received by the ElStat, all the iron and steel plants of the country are included in the EU ETS.
- For the period 1990-2004, information has been collected through questionnaires developed according to the guidelines described in the Commission Decision 2004/156/EC from all individual plants in Greece, in the framework of the formulation of the NAP, according to the EU Directive 2003/87/EC.

- Data regarding steel production are provided by the ElStat for the years 2004- 2018 (in the previous years the relevant Prodcom code did not exist). These data are actually the reported activity data. Especially for 2014 activity data used are received from the data published in the World Steel Association database as data from ElStat are not yet publicly available.
- Emissions from lime consumption are also included in this sub-category, as suggested by the 2006 IPCC guidelines. Data are generally plant specific, deriving from the EU ETS verified reporting of the plants and the reporting performed for the NAP formulation for the previous years. The abrupt reduction in emissions since 2012 can be attributed to the cease of operation of two plants in Greece.
- The emission factor used for the estimation of methane emissions is the default CORINAIR 2013 (SNAP 040207) emission factor (10g/Mg of iron produced), as no emission factor is mentioned in the IPCC guidelines for CH_4 emissions in EAF.

4.11.3 Uncertainty and time-series consistency

The uncertainty associated with the CO_2 EF is quite low (5%) since all the carbon content is reported by the plants. The same value has been used for the uncertainty of the activity data, accounting mainly for the weighting error in the plant specific reports of the ETS system. As regards to the CH_4 emissions, the uncertainty values are at the same level, in absence of any other data.

The methodology used for the CO_2 emissions is country specific and is the same for the whole time-series. In order to ensure the consistency of the time-series, a recalculation of the previous years has been implemented in 2009.

In specific and following the suggestions of the ERT in-country review of Greece that took place in September 2008, the fraction of total carbon consumption used for the estimation of emissions accounted as residual carbon in slag has been estimated. This was found to be 0.29%. However, the quantities of furnace and vat slag are quite insignificant (0.05% of the overall). According to the same suggestions, once the above mentioned fraction has been found to be insignificant, the CO_2 IEF of years 2005-2007 should be used for the estimation of the entire time-series. In order to do so, the inventory team has collected data on steel production by the ElStat for the years 2004-2006 and used it to estimate the IEF and recalculate emissions. All the information regarding the procedure has been provided in the 2009 NIR. It should be also noted that, in the 2009 centralised review, the ERT have concluded that the recalculation methodologies used are in line with the 2006 IPCC Guidelines.

In general, CO_2 emissions from steel production followed an increasing trend, reaching a maximum value of 237.14 kt in 2007. Then and in the next three years emissions are decreased by 48.20%, as a result of the decreased production. This has been also cross-checked with the general trends in the constructions area, which is safe to be considered as a driver since according to the “2008 Sustainability Report of the world steel industry”, published by the World Steel Association, the

Infrastructures sector seems to be the main application of the steel production (50% of steel use in 2007 is designated for use in infrastructure). One out of five plants operating ceased its operation during 2012, reporting zero emissions. In 2013 one more plant ceased its operation. Therefore, a reduction of emissions can be attributed to this in addition to the economic recession that is also present in the Construction Sector. However, in 2014 the emissions have slightly increased (1.77%), in 2015 a decrease of 12.76% was again presented, followed by an increase of 19.84% in 2016. Finally, the annual decrease of emissions between 2023 and 2022 was -20.43% and overall -37.89% compared to the 1990 emissions.

Figure 4.11 presents the timeseries of production and CO_2 emissions.

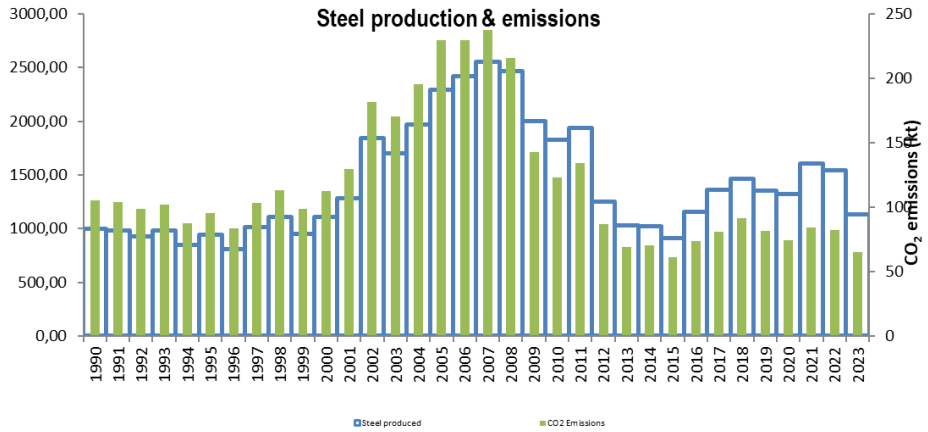


Figure 4.11 Steel production and CO_2 emissions (in kt) for the period 1990 – 2022

On the basis of the completed and detailed data of 2005-2007 a country specific CO_2 emission factor is estimated (0.096 t/t). This emission factor has been calculated a little lower in 2008 (0.087 t/t), and quite lower in the next years. In specific in 2014 and 2015 it was 0.068 and 0.067 t/t, respectively. However, in any case it is close to the default emission factor of 0.080 t/t indicated for electric arc furnaces.

The difference between 2008 and 2009 IEF can be attributed to annual variations of the reduced agents/fuels used and their respective carbon content as well as other material used (e.g. scrap). In addition, it should be noted that (a) emissions from national statistics have been cross checked with the values provided by the World Steel Association and are in line with the slab quantities and (b) the information on the quantities of the carbon content of the materials and the emissions used in the Inventory are provided by reports of the ETS system which have been verified by accredited verifiers.

4.11.4 Source-specific QA/QC and verification

In order to ensure the quality of the estimation, each plant's reports are checked in two ways: first following the time-series trend of the specific plant and secondly by comparing each plant's report

with the general trend for the current year. The data reported in each year are calculated in the specific spread sheet of the year, while all the data are gathered in the Input File of the Inventory at the end of the annual inventory circle.

As an additional quality assurance procedure, plant specific production data are also collected by the inventory team whenever available. Also, less detailed data are collected by international sources, such as the World Steel Association which are cross checked with the data provided by the the Hellenic Statistical Authority.

4.11.5 Recalculations

No recalculation has been performed during this submission.

4.11.6 Planned improvements

The current submission can be considered satisfactory.

4.12 Ferroalloys production (CRT Source Category 2.C.2)

4.12.1 Description

Ferroalloy production involves a metallurgical reduction process that results in CO_2 emissions. The carbon in the electrodes captures the oxygen from the metal oxide to form CO_2. In addition, the calcination of carbonates fluxes such as limestone or dolomite contributes to these emissions.

The CO_2 emissions in 2023 were zeroed due to the closure of the sole plant operating since 1963 in Greece. As there was only one unit operating in Greece data for the previous years is plant specific and are characterized by fluctuations.

4.12.2 Methodology

The estimation of CO_2 emissions from ferroalloys production is based on the laterite consumption and the carbon content of it, as well as on the consumption of fuels used as reducing agents and their carbon content.

- Activity data are considered as confidential since there is only one industry operating in Greece.
- Activity data for 2005-present derive of the annual verified reports of the industry under the EU ETS.
- Activity data for the period 2000-2004 derive of the reports of the plant during the formulation of the NAP and from additional information concerning the primary fuels and their carbon content for the years 2000-2013. The above mentioned data are combined with supplementary information relevant to the plant production in order to complete the missing data for the period 1990-1999. For the same period of estimation, the carbon content of laterite used is less than 2%, according to plant specific information. Also, detailed information on the emissions from both laterite and reducing agents' use for the years 2000-2017 has been provided by the plant.

4.12.3 Uncertainty and time-series consistency

The uncertainty estimates for both activity data and emission factor are decreased by the fact that plant-specific fuel requirement, laterite consumption and carbon content have been provided by the specific industry. However, this uncertainty should take into account the fact that the provided data cover the years 2000-2020 and for the rest years of the time series the Ni production has been used as a driver. The uncertainty estimate in both cases (AD and EF) has been considered, therefore 7%.

As regards to the time-series consistency, as it has been already mentioned, years 1990-1999 have been estimated using the Ni production as a driver, in absence of any other available data by the industry, whereas years 2000-present are reported on the basis of plant specific data. This assures

that the same method has been used for the whole time series, enabling the achievement of time-series consistency.

Figure 4.12 presents the emission levels for the whole time-series. As it can be seen the trend follows the trend of other production sectors, indicating an important decrease in 2009 (-45.53% comparing to 2008), as a result of the economic crisis. However, this is partly counterbalanced by an important increase in 2010, which is attributed to the system's recovery from the economic shock experienced in 2009 (51.01% increase). In 2011 a new increase in this sector is presented reaching 27.39% comparing to 2010. In 2018 a significant decrease in emissions occurred equal to 11.32% compared to 2017, followed by another decrease of 13.6% in year 2019. In 2020 a severe decrease was reported equal to -48.13%, followed by an additional reduction in the coming years.

This can be attributed to the very low production of Ni during this year, which is linked with the suspension of operation in the plant, due to management and financial problems they are facing. On February 1, 2022, the government announced a public tender process for the purchase of the only plant operating in Greece and the termination of 1,060 employees.

Regarding raw materials for Ni Production emissions derive from the use of Laterite as described above, as well as Coal, Lignite, Metallurgical coke, Crushed coke, Electrode paste, and Dolomitic limestone. LPG is not used as a reducing agent, therefore, their associated emissions are included under energy sector. During the last years the use of coal is the most significant, while the use of lignite was zeroed. Laterite and Metallurgical coke are the next more important agents used.

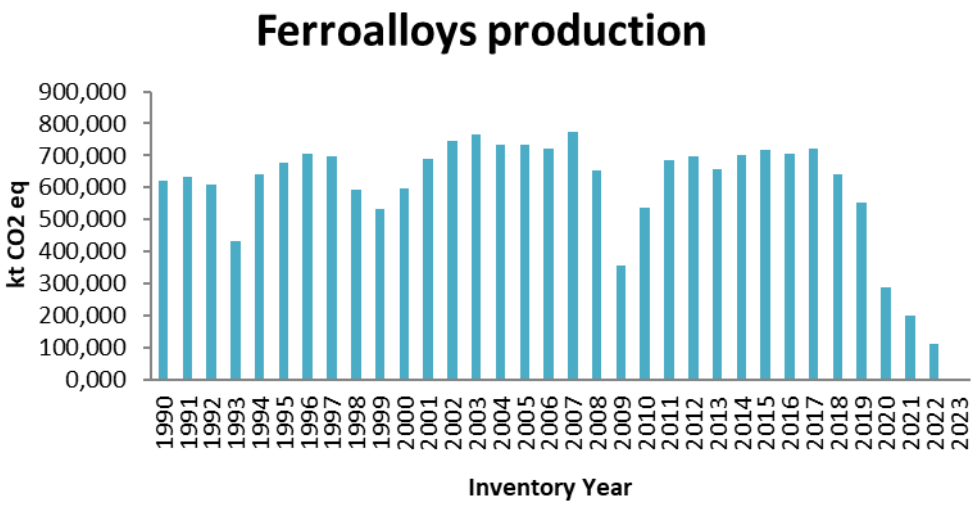


Figure 4.12 ***CO_2 emissions (in kt) from Ferroalloys Production for the period 1990 – 2023***

4.12.4 Source-specific QA/QC and verification

In absence of any other data available, the QC tests include the collaboration with the experts from the energy sector, in order to make sure that the emissions from fuels used as reducing agents are not double counted and the estimation of emissions using the average country-specific EF and the

Ni production to make sure that the emissions calculated in both ways do not differ to a high level. It should be also noted that default EF values are not easy to be found in literature for Ni production, making more difficult the estimation with different tiers.

The QC procedures refer to the checking of the IEF in order to ensure that in general the factor is stable. The deviation of the IEFs is attributed to the different percentages of the raw material mixtures throughout the years of the time-series.

4.12.5 Recalculations

No recalculation was performed in this submission.

4.12.6 Planned improvements

The current submission can be considered satisfactory.

4.13 Aluminium production (CRT Source Category 2.C.3)

4.13.1 Description

Primary aluminium production is responsible for emissions of CO_2 and PFCs. Carbon dioxide is produced when, during electrolysis, the carbon of the anode reacts with alumina (Al_2O_3), and also during the anode baking process due to the pitch volatiles combustion and the combustion of baking furnace packing material (coke). Two PFCs (CF_4 and C_2F_6) are formed during the phenomenon known as the anode effect, when the aluminium oxide concentration in the reduction cell electrolyte is low.

Aluminium production is a key category by level. Emissions of CO_2 and PFC from aluminium production in 2023 (***Table 4.19***) accounted for 3.28% and 0.70%, respectively, of total GHG emissions from *Industrial processes*. CF_4 and C_2F_6 emissions in 2023 accounted for 83.15% and 16.85%, respectively, of the PFC emissions (in CO_2 eq.) and 14.60% and 2.96%, respectively, of the total CO_2 emissions derived from Aluminium production.

CO_2 emissions have increased since 1990 by 32.51%, while PFC emissions have increase since 1995 by 12.58%. In should be noted that emissions of CO_2 depend directly on aluminium production, while PFC emissions are influenced as well from actions on the restriction of the anode effect.

Table 4.19 CO_2 emissions (in kt) and PFC emissions (in kt CO_2eq) from primary aluminium production for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2 emissions	225.39	229.48	230.64	222.44	207.87	197.12	197.12	199.77	219.99	240.87	244.86
PFC emissions	171.09	171.93	168.83	101.56	63.23	56.52	48.32	111.16	135.83	88.33	97.97
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CO_2 emissions	244.05	246.85	250.85	250.97	249.08	247.66	249.16	250.32	192.39	207.22	242.03
PFC emissions	60.86	58.55	52.24	47.81	47.54	40.72	39.29	49.58	23.57	35.41	41.16
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CO_2 emissions	270.56	276.63	276.87	286.71	291.281	288.116	289.52	291.36	294.08	298.57	301.68
PFC emissions	52.53	74.35	71.57	59.25	79.41	73.91	88.95	94.36	106.63	85.82	63.06
Year	**2023**										
CO_2 emissions	298.67										
PFC emissions	63.63										

4.13.2 Methodology

The estimation of emissions from aluminium production is performed in close collaboration with the sole plant operating in Greece and since 2013 ETS verified reports are also provided to the inventory team.

Carbon dioxide emissions from primary aluminium production are calculated using a highly detailed methodology, tracking the carbon content throughout the process. The methodology is based on the 2006 IPCC Tier 3 method, with small interventions that increase the certainty of the estimations. The equations used are described below.

Prebake Anode Emissions

C_{CO+CO2} (t) = [(NAC – Waste) * (100 - %Ash_a - %S_a)/100] - [C_{inCF4} + $C_{in\ C2F6}$]

Where:

C_{CO+CO2}: the carbon content of CO and CO2 emissions from prebake anode process

NAC: net prebake anode, t

Waste: the quantity of the carbonate sediment that is removed from the basins, t

S_a and Ash_a: the sulphur and ash content in the baked anodes, wt%

and C_{inCF4} , $C_{in\ C2F6}$: the carbon that is bound by the production of PFCs and does not participate in the CO/CO_2 emissions.

For the distinction of C participating in CO2, the rate λ is used (C_{CO} / C_{CO2} = λ *44 / 28), based on the measurements of the fuel gases analyzers that operate on a permanent base. The outcome is then multiplied by 44/12 to express the CO2 emitted.

Pitch Volatiles Combustion Emissions

CO_2(t) = (GA – H_w – BA – WT) *44/12

Where :

GA: initial weight of green anodes, t

H_w: hydrogen content of GA, t, estimated as 0.005*GA

BA: baked anode production, t

WT: Waste tar collected, t, which is considered insignificant.

Bake Furnace Packing Material Emissions

$$CO_2(t) = \{ [PC*(100 - \%Ash_a - \%S_a -)/100] – [WPC* (100 - \%Ash_b - \%S_b) /100] \} *44/12$$

Where:

PC: packing coke, t

WPC: Waste packing coke, t

S_a and Ash_a: the sulphur and ash content in packing coke, wt%

S_b and Ash_b: the sulphur and ash content in the waste packing coke, wt%

Data are provided by the plant for years 2005-2012. Since detailed data for the previous years are not available, emissions of years 1990-2004 have been recalculated using the Overlap method in line with the 2006 IPCC Guidelines. It should be noted that the production methodology applied is Centre Worked Prebake with Feed Point System (PFPB methodology). Data since 2013 are provided by the verified ETS reports.

Aluminium production data are directly provided by the plant and are considered confidential. However, publicly available data from the US Geological Survey, the UN Commodity Statistics Database and the Greek Mining Enterprises Association are also used for QA/QC reasons. According to the recommendation made by the previous ERTs, Greece is reporting aluminium production based on these data, although the estimations are based on the more detailed and accurate production quantities provided directly by the plant. It should be mentioned that the reported values are the ones provided by the US Geological Survey, since they cover the whole of the time-series.

PFC emissions estimates are based on anode effect performance by calculating the anode effect overvoltage statistic (Overvoltage method) and are provided directly to the inventory team by the sole plant operating in Greece. This methodology concerns measurements and recordings that are being performed concerning the parameters of the equation used for the CF_4 emission's calculation, namely the overvoltage and the aluminium production process current efficiency. The EF is estimated based on EF=Over-Voltage Coefficient*AEO/CE. The Over-Voltage Coefficient value used by the plant is 1.16 (the updated default one of 2006 IPCC Guidelines), while the Anode Effect Overvoltage (AEO) and Current Efficiency (CE) are measured for each series of electrolytic cells (there are three series).

The C_2F_6 emissions are then calculated by using the following formula:

$$C_2F_6 = 0.1 \bullet CF_4$$

4.13.3 Uncertainties and time-series consistency

The uncertainties regarding the CO_2 emissions relate mainly to the uncertainty of the production activity data provided by the plant, as well as to the uncertainty of the emission factor. Both values are quite low, at 2%, since highly detailed data are provided by the plant concerning both the EF and the quantities inserted in the described equations.

As regards to PFCs emissions, the associated uncertainty is, again, not very high (3% for AD and 6% for EF). All the data and EF are plant-specific and the methodology takes into account the smelter-specific operating conditions.

Emissions have been calculated in the same way throughout the time series. The IEF regarding PFCs emissions is not stable throughout the time-series, mainly because PFCs emissions are not directly associated to the aluminium production but to the anode effect.

The trend of the emissions is depicted in the ***Figure 4.13***. PFC emissions from primary aluminium production presented a continuous decrease from 1990 to 1996. Then and for a four year period (1997 – 2000) emissions almost doubled compared to 1996. Since 2001, this trend changes again and emissions were about the same as in 1995 – 1996. The next increase has happened in 2008, followed by an intense decrease by 52.45% in 2009 and an increase from 2010 to 2014, which is in line with the reported production levels. However, PFC emissions decreased in 2015 by -17.21% since 2014 and increased by 34.03% from 2015 to 2016. Then PFC emissions decreased by 6.94% from 2016 to 2017 and increased by 20.35% from 2017 to 2018. A smaller increase of 6.08% was also reported between the years 2018 and 2019, followed by a 13% increase between 2019 and 2020. In 2021 PFC emissions finally presented a decrease of -19.51% and in 2022 an additional decrease of -26.5%.

According to the Greek QA/QC procedures, information has been provided by the plant, concerning the above mentioned trend. This information includes the following:

- During the period 1993-1998, one aluminium series did not operate leading to the decrease of PFCs emissions (it should be mentioned that the plant disposes three operating aluminium series. All the aluminium series were in place in 1990 and continue to be operating since).
- During 1998-2000, the plant was facing some operational problems.
- Since 2000, the accuracy is improved by estimating the over voltage in mV.
- The difference between 2000 and 2001 is attributed in the exemption of negative overvoltage values.
- Since 2001 the production process has been significantly improved leading to a decrease in emissions.
- The plant has also communicated that the increased emissions of 2008 is attributed to the operational crisis of the electrolysis procedure in August-September of the same year. The problem has been caused by the grain size of alumina, and was resolved in during the next year.

- The decrease in emissions both for CO2 and PFCs in 2009 is related with the economic recession, influencing all industrial sectors of the country, while during the next two years an increase took place.

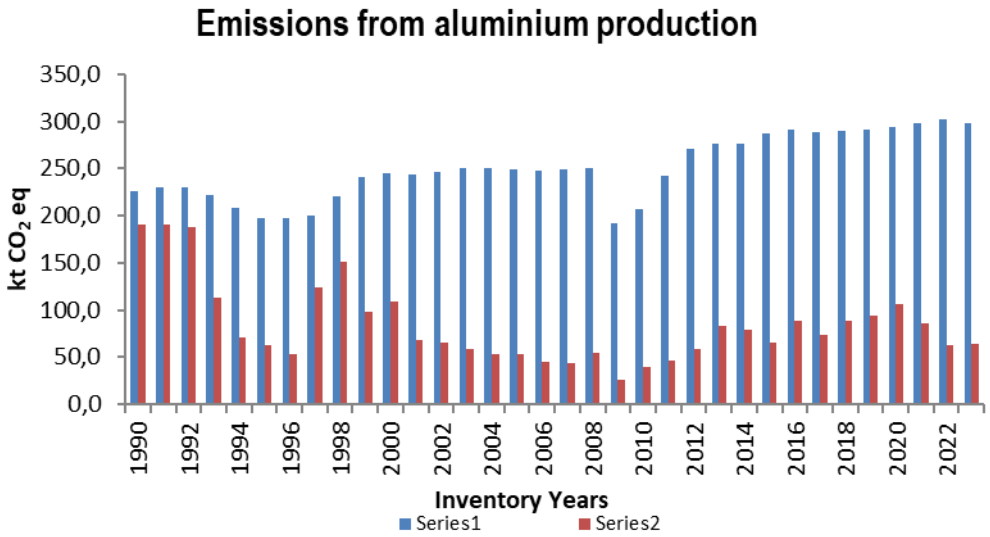


Figure 4.13 ***CO_2 and PFCs emissions (in ktCO_2 eq) from aluminium production for the period 1990 – 2023***

4.13.4 Source-specific QA/QC procedures and verification

In the recent years, the estimations of emissions from aluminium production are being conducted in close cooperation with the respective Greek plant, enabling the improvement of the transparency of the inventory, for both CO_2 and PFCs emissions.

Moreover, additional information, such as the Environmental Study and other reports provided by the plant, has enabled the inventory team to better understand the operating situation of the aluminium series and anode effect. In that context, the plant has informed the inventory team on the internal QA/QC procedures undertaken, which include the internal archiving of information, compatible with the Quality Management Procedure of their Internal Quality System (certified to ISO 9001). It should be also noted that, according to information received by the plant, in 2003 the methodology used for the PFCs emissions' calculation has been approved by independent auditors of the Pricewaterhouse Coopers (PwC). In addition, the detailed information provided for the years 2005-2012 has been also verified by accredited verifiers and since 2013 all information are verified under the ETS system.

The Inventory Team's source specific QA/QC procedures include the following:

- The archiving of all information received in line with the procedures of the QC system.
- Comparison of the emission factors with the default ones and communication with the plant, if needed in order to ensure the quality of the emissions.

- Collection of information / explanation of the trend of the time series, in cooperation with the above mentioned plant.

As a supplementary QA/QC test the IEF of the PFCs has been compared to the default reported in the IPCC Guidelines. The two values are quite close to the default values reported in the study of the Canadian aluminium plants, for Centre Worked Prebaked Technology.

External sources are being used as alternative information providers in order to validate the production reported by the plant. These sources include the Greek Mining Enterprises Association, and the United Nations Industrial Commodity Statistics Database. Data have been also found in the US Geological Survey and they are the same as the ones reported by the Greek Mining Enterprises Association. As already reported during previous reviews there has been a pressure on Greece to publish the confidential data reported by plant. In the 2010 and 2011 reviews Greece has also been recommended to report the publicly available data instead of the plant specific ones. In order to resolve this issue, and respecting the accuracy principle of the inventory, the plant specific production data is being used and the publicly available information is reported to help understand the timeseries trend. During the 2012 in country review the publicly available production data which are reported have been approved by the review team as there were minor differences with the confidential plant specific data.

The IEF of the CO_2 has also been compared to the default one. The average factor of the years for which detailed information is available, namely 2005-present is 1.59 t/t Al, in the range of the default values of 1.5 (1996 IPCC Guidelines) and 1.6 (2006 IPCC Guidelines).

4.13.5 Recalculations

No recalculations were reported in this category during this submission.

4.13.6 Planned improvements

No planned improvements are reported.

4.14 Lead Production (CRT Source Category 2.C.5)

CO_2 emissions from Lead production in 2022 (***Table 4.20***), account for 0.07% of total GHG emissions from *Industrial Processes*. Lead production does not constitute a key source category, while emissions in 2021 presented a decreased by 38.10 % from 1990.

Table 4.20 CO_2 emissions (in kt CO_2) from lead production for the period 1990 – 2023

Year	Lead production (kt)	CO_2 Emissions (kt)
1990	26.20	13.62
1991	30.71	15.97
1992	27.96	14.54
1993	28.81	14.98
1994	28.40	14.77
1995	20.40	10.61
1996	11.54	6.00
1997	19.30	10.04
1998	18.00	9.36
1999	22.00	11.44
2000	18.24	9.48
2001	28.62	14.88
2002	29.30	15.24
2003	6.00	1.84
2004	4.00	0.80
2005	7.00	2.36
2006	14.50	6.26
2007	19.00	8.60
2008	34.31	14.32
2009	27.03	10.85
2010	22.20	8.34
2011	22.00	8.24
2012	23.10	8.81
2013	23.00	8.76
2014	21.80	8.14
2015	19.20	6.78
2016	21.30	7.88
2017	18.70	6.52
2018	19.80	7.10
2019	20.50	7.46
2020	23.10	9.17

2021	23.0	10.32
2022	21.8	8.12
2023	19.2	8.43

4.14.1 Methodology

According to the IPCC 2006 Guidelines, the Tier 1 methodology is applied for the calculation of CO_2 emissions from lead production. CO_2emissions from lead production are estimated according to the following equation (default methodology, IPCC 2006):

$$E = DS \cdot EF_{DS} + ISF \cdot EF_{ISF} + S \cdot EF_S$$

where, E=CO_2 emissions from lead production, (t), DS = quantity of lead produced by Direct Smelting, (t), EF_{DS} = emission factor for Direct Smelting, (t CO_2/t lead product), ISF = quantity of lead produced from the Imperial Smelting Furnace, (t), EF_{ISF} = emission factor for Imperial Smelting Furnace, (t CO_2/t lead product), S = quantity of lead produced from secondary materials, (t), E_{FS} = emission factor for secondary materials, (t CO_2/t lead product).

The following are noted in relation to the application of the above equation:

- For all the years the emission factor used is the default emission factor suggested by the IPCC Guidelines (IPCC, 2006) based on 80% ISF and 20% DS. The default EF equals to 0.52 t of CO_2/ t lead. In addition, concerning Treatment of Secondary Raw Materials the default emission factor used equals to 0.2 t of CO_2/ t lead.
- Lead production activity data throughout the time series derive from international sources (US Geological Survey) as there is a completeness in data availability since 1990.

4.14.2 Uncertainty and time-series consistency

The uncertainty arisen by the currently implemented methodology has been considered equal to 20% for the emission factor and 2% for the production data used. The high value of the emission factor's uncertainty is attributed to the fact that the default EF has been used that is prone to be different from the actual value. Concerning the uncertainty of the activity data the above mentioned value accounts mainly from the uncertainty of the produced lead quantity.

The time-series consistency of emissions is assured by applying consistent methodologies and verified activity data in line with IPCC guidelines. In the case of lead production, the default methodology has been used for the whole time-series.

The trend of the time-series can be seen in ***Figure 4.14***. As it can be seen from this Figure, the CO_2 emissions timeseries present fluctuations. More specifically, for the years 2003-2005 there was a low level of CO_2 emissions resulting from a low level in production. In 2008 there was an intense increase in emission equal to 66.55% compared to 2007. For the years 2008 to 2010 there was a decrease in emissions as a result of the economic recession in the country, followed by fluctuations

in emissions. In general, since the same emission factor has been used for all the years of the time series the changes of the emissions indicate the general change of the production level.

Regarding the secondary production the average amount since 2000 is 7.43 kt. The average percentage of secondary production compared to the overall lead production is 44.46% since 2005.

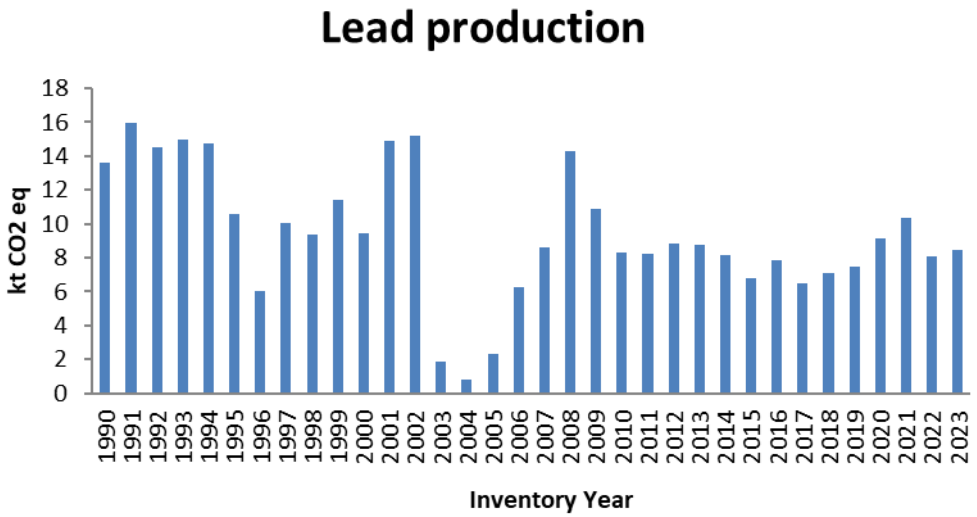


Figure 4.14 CO_2 emissions (in kt) from Lead Production for the period 1990 – 2023.

4.14.3 Source-specific QA/QC and verification

Lead production source category was first included in the Greek inventory in 2015 submission according to the 2006 IPCC Guidelines.

According to the QA/QC procedures, all the information received archived in the Input File of the Greek Inventory system. Additionally, the plant specific data are being cross-checked with confidential data collected by the ElStat, depending on data availability.

4.14.4 Recalculations

No recalculation was reported in this submission.

4.14.5 Planned improvements

Communication with the specific plants related to lead production in Greece is being encouraged to be able to have more detailed data in order to improve the Tier of the methodology.

4.15 Zinc Production (CRT Source Category 2.C.6)

4.15.1 Description

CO_2 emissions from zinc production in 2023, account for 0.38% of total GHG emissions from *Industrial Processes*. Zinc production does not constitute a key source category. Emissions are summarized in ***Table 4.21***.

Table 4.21 CO_2 emissions (in kt CO_2) from zinc production for the period 1990 – 2023

Year	Zinc production (kt)	CO_2 Emissions (kt)
1990	26.70	45.92
1991	39.00	67.08
1992	26.20	45.06
1993	24.85	42.75
1994	17.20	29.58
1995	14.50	24.94
1996	13.60	23.40
1997	17.80	30.62
1998	29.10	50.05
1999	19.62	33.74
2000	20.34	34.98
2001	20.46	35.19
2002	30.00	51.60
2003	30.40	52.29
2004	0.00	NO
2005	1.30	2.24
2006	16.41	28.23
2007	18.00	30.96
2008	20.30	34.92
2009	18.13	31.18
2010	19.97	34.34
2011	19.56	33.65
2012	20.91	35.97
2013	21.00	36.12
2014	22.70	39.04
2015	14.90	25.63
2016	18.90	32.51
2017	18.30	31.48
2018	20.30	34.92
2019	21.80	37.50

2020	28.10	48.33
2021	23.20	39.90
2022	23.35	40.16
2023	24.11	41.47

4.15.2 Methodology

According to the IPCC 2006 Guidelines, the Tier 1 methodology is applied for the calculation of CO_2emissions from zinc production. CO_2emissions from zinc production are estimated according to the following equation (default methodology, IPCC 2006):

$$E = Zn \cdot EF_{default}$$

where, E is CO_2 emissions, Zn is the zinc production, and $EF_{default}$ is the default emission factor.

The following are noted in relation to the application of the above equation:

- For all the years the emission factor used is the default emission factor suggested by the IPCC Guidelines (IPCC, 2006) based on weighting of known emission factors (60% Imperial Smelting, 40% Waelz Kiln). The default EF equals to 1.72 t of CO_2/ t zinc.
- Zinc production activity data throughout the data series derive from international sources (US Geological Survey) as there is a completeness in data availability since 1990.

4.15.3 Uncertainty and time-series consistency

The uncertainty arisen by the currently implemented methodology has been considered equal to 20% for the emission factor and 2% for the production data used. The high value of the emission factor's uncertainty is attributed to the fact that the default EF has been used that is prone to be different from the actual value. As regards to the AD accuracy, the uncertainty value accounts mainly from the uncertainty of the produced zinc quantity.

The time-series consistency of emissions is assured by applying consistent methodologies and verified activity data in line with IPCC guidelines. In the case of zinc production, the default methodology has been used for the whole time-series. The trend of the time-series can be seen in ***Figure 4.15***.

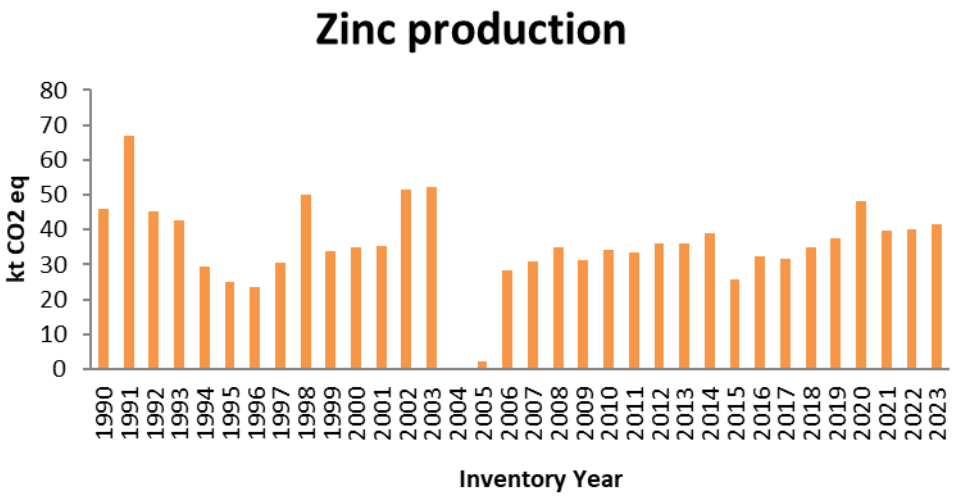


Figure 4.15 CO_2 emissions (in kt) from Zinc Production for the period 1990 – 2023.

As it can be seen from this Figure, the CO_2 emissions timeseries present fluctuations. More specifically, for 2004 there was a cease in production and in 2005 a very low production level leading to low CO_2 emissions.

Since the same emission factor has been used for all the years of the time series the changes of the emissions indicate the general change of the production level.

4.15.4 Source-specific QA/QC and verification

Zinc production source category was first included in the Greek inventory in 2015 submission according to the 2006 IPCC Guidelines. According to the QA/QC procedures, all the information received is archived in the Input File of the Greek Inventory system. Additionally, the plant specific data are being cross-checked with confidential data collected by the ElStat, depending on data availability.

4.15.5 Recalculations

No recalculation was performed during this submission.

4.15.6 Planned improvements

Communication with the specific plants related to Zinc production in Greece is being encouraged to be able to have more detailed data in order to improve the Tier of the methodology.

4.16 Lubricant Use (CRT Source Category 2.D.1)

4.16.1 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, included in the IPPU sector.

CO_2 emissions from lubricant use in 2023 (***Table 4.21***), accounted for 0.54% of total GHG emissions from *Industrial Processes*. Lubricant use does not constitute a key source category. The emissions from Lubricant Use are summarized in ***Table 4.22***.

Table 4.22 CO_2 emissions (in kt CO_2) from Lubricant Use for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO_2 emissions	77.83	50.71	51.30	50.12	50.71	43.63	39.50	47.17	30.66	37.73	33.02	46.58	31.84	37.73
Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions	41.27	47.17	71.93	60.14	40.68	27.12	23.58	21.82	20.64	22.40	28.30	29.48	27.71	30.89
Year	2018	2019	2020	2021	2022	2023								
CO_2 emissions	33.39	48.73	40.05	34.94	42.76	49.54								

4.16.2 Methodology

CO_2 emissions are calculated according to the following Equation with aggregated default data for the limited parameters available and the ODU factor based on a default composition of oil and greases in total lubricant figures (in TJ units):

$$CO_2 \text{ Emissions} = LC \bullet CC_{\text{lubricant}} \bullet ODU_{\text{lubricant}} \bullet 44/12$$

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

The IPCC Default ODU factor for total lubricants that was used is 0.2, assuming 90% lubricating oil consumption and 10% grease consumption and rounded to one significant digit. The CC for lubricants was considered the default carbon content of 20.0 kg C/GJ (on a Lower Heating Value basis), as suggested in the 2006 IPCC guidelines and the NCV was 40.2TJ/kt.

Concerning the activity data for the years 1990-present they derive from the energy balance in close collaboration with the Energy sector experts in order to avoid double counting.

4.16.3 Uncertainty and time-series consistency

The uncertainty of both the activity data is and the EF for the CO_2 emissions estimation 5%, on the basis that the activity data derive from the energy balance and the EF is the default one suggested by the 2006 IPCC Guidelines.

The time-series of the CO_2 emissions show important fluctuations. In 2006 a maximum in emissions was reached while for the recent years emissions experience a strong decrease that was very intense for 2012 (***Figure 4.16***). However, in 2013 the CO_2 emissions were reported slightly higher compared to 2012, which is connected to the similar lubricants quantity acquired by the national energy balance. Finally, in 2022 an increase of 22.4% in emissions since 2021 was reported.

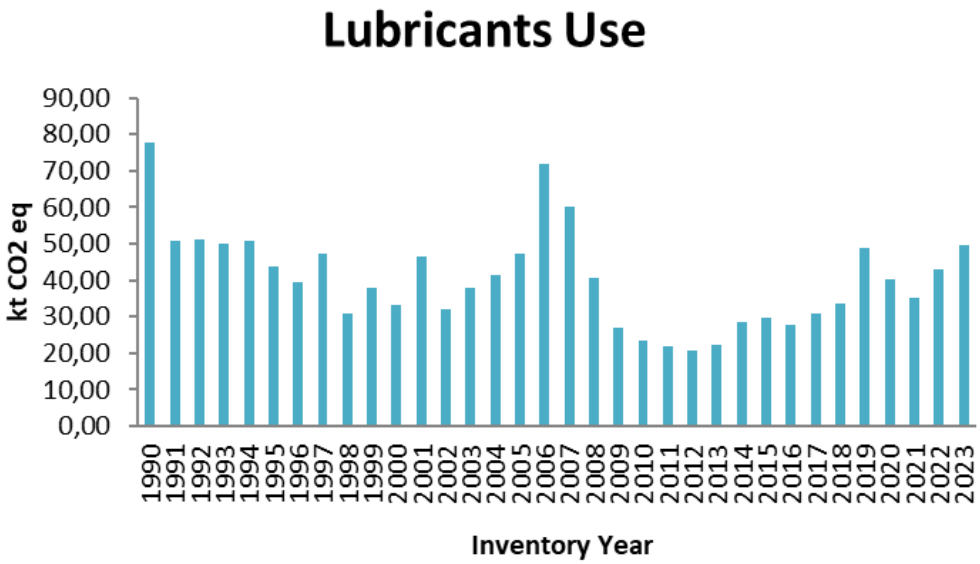


Figure 4.16 CO_2 emissions (in kt) from Lubricant Use for the period 1990 – 2023.

4.16.4 Source-specific QA/QC and verification

As there is absence of other data availability, the QC tests include the collaboration with the experts from the energy sector, in order to make sure that the emissions from lubricant use are not double counted. It should be also noted that lubricant quantity data are not easy to be found in literature, making more difficult the emissions estimation with different tiers.

4.16.5 Recalculations

No recalculation was reported in this submission.

4.16.6 Planned improvements

No improvements are planned for this category.

4.17 Paraffin Wax Use (CRT Source Category 2.D.2)

4.17.1 Description

Paraffin waxes included in this category are separated from crude oil during the production of light lubricating oils. 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 paraffins are combusted during use (e.g., candles), and when they are incinerated with or without heat recovery or in wastewater treatment (for surfactants).

CO_2 emissions from Paraffin Waxes Use in 2021 (***Table 4.23***), account for 0.16% of total GHG emissions from *Industrial Processes*. Paraffin Wax use does not constitute a key source category. The emissions from Paraffin Wax Use are summarized in ***Table 4.23***.

Table 4.23 CO_2 emissions (in kt CO_2) from Paraffin Wax use for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
CO_2 emissions	50.70	50.70	67.60	67.60	50.70	33.80	33.80	16.90	16.90	16.90	16.90	16.90	9.66	6.64
Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions	16.90	5.92	7.61	9.80	12.84	14.37	18.91	18.25	13.39	13.10	15.66	14.18	15.76	15.11
Year	2018	2019	2020	2021	2022	2023								
CO_2 emissions	14.57	14.40	14.71	15.01	14.91	14.76								

4.17.2 Methodology

CO_2 emissions are calculated according to the following equation with aggregated default data for the limited parameters available:

$$CO_2 \text{ Emissions} = PW \bullet CC_{wax} \bullet ODU_{wax} \bullet 44/12$$

where, *CO_2 Emissions* = CO_2 emissions from paraffin wax use, (t CO_2), *PW*= total wax consumption, (TJ), CC_{wax} = carbon content of wax (default), (t C/TJ = kg C/GJ), ODU_{wax} = ODU factor for paraffin wax(fraction), 44/12 = mass ratio of CO_2/C.

According to the IPCC 2006 Guidelines (Tier 1) it can be assumed that 20 percent of paraffin waxes are used in a manner leading to emissions, mainly through the burning of candles, leading to a default ODU factor of 0.2. The CC for the waxes was considered the default carbon content of 20.0 kg C/GJ (on a Lower Heating Value basis), as suggested in the 2006 IPCC guidelines and the NCV was 40.2TJ/kt.

In 2020 submission a recalculation of the whole time series was performed based on the reviewers' comments. Therefore, data on exports and imports of candles were also used for years 2010-2018 from EUROSTAT [DS-016890]. In particular, according to the IPCC 2006 Guidelines (Tier 1) it

can be assumed that 20 percent of paraffin waxes are used in a manner leading to emissions, mainly through the burning of candles, leading to a default ODU factor of 0.2. For years prior to 2010 the surrogate method was used to ensure time series consistency.

4.17.3 Uncertainty and time-series consistency

The uncertainty of both the activity data is and the EF for the CO_2 emissions estimation 5%, on the basis that the activity data derive from the energy balance and the EF is the default one suggested by the 2006 IPCC Guidelines.

The time-series of the CO_2 emissions show important fluctuations. For the years after 1997 low CO_2 emissions are reported until the recent years (***Figure 4.17***). In particular, a decrease of 25% was reported for the years 1993 to 1994, followed by a decrease by 33.33% for the years 1994 to 1995 and 50% from 1996 to 1997. For 2012 there was a decrease by 26.6% in emissions compared to 2011, followed by an increase by 19.55% in 2014 compared to 2013 emissions. A decrease by 9.46% was also reported in 2015 compared to 2014, while an increase of 11.15% was presented for 2016. Over the last years the emissions appear stable, presenting a decrease of 0.64% in 2022 compared to 2021.

All activity data are acquired by the national balance for production calculations and from EUROSTAT for the imports and exports on waxes. After a personal communication with the National Statistical Authority the inventory team was informed that AD are confidential since the number of plants producing paraffin waxes is lower than three. Therefore, the small number of plants operating in Greece is also the reason for the emissions' fluctuations.

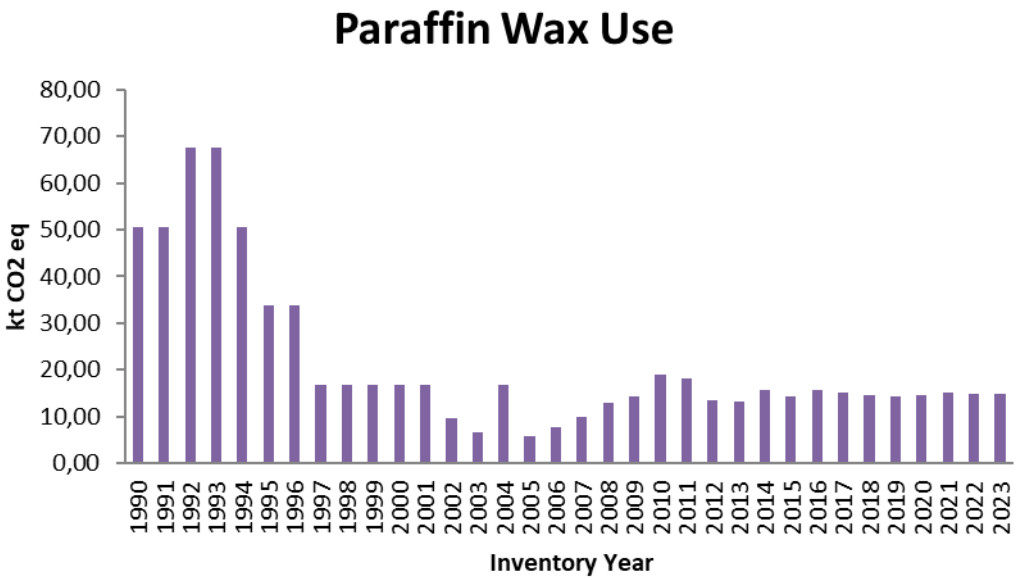


Figure 4.17 CO_2 emissions (in kt) from Paraffin Wax Use for the period 1990 – 2023.

4.17.4 Source-specific QA/QC and verification

In absence of other data availability, the QC tests include the collaboration with the experts from the energy sector, in order to make sure that the emissions from paraffin wax use are not double counted. It should also be mentioned that data availability from other sources, such as literature review, studies, etc. is limited, making more difficult the emissions estimation with higher tiers.

4.17.5 Recalculations

No recalculation was performed in this submission.

4.17.6 Planned improvements

No improvements are planned for this category.

4.18 Use of urea as a catalyst (CRT Source Category 2.D.3)

4.18.1 Description

In this category CO2 emissions from use of urea-based additives in catalytic converters (non-combustive emissions) are included.

CO_2 emissions from urea used as a catalyst in 2023 (***Table 4.24***), account for 0.08% of total GHG emissions from *Industrial Processes*.

Table 4.24 CO_2 emissions (in kt) from Use of urea as a catalyst for the period 2008 – 2022

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
CO_2 emissions	0.01	0.07	0.11	0.30	0.87	1.60	2.06	2.52	2.98	3.44	3.92	5.34
Year	2020	2021	2022	2023								
CO2 emissions	5.17	5.71	6.80	7.10								

4.18.2 Methodology

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories include CO2 emissions from the use of urea-based additives in catalytic convertors as a new source of greenhouse gas emissions. The method described in the 2006 IPCC Guidelines for calculation of CO2 emissions due to the use of urea- additive based selective catalytic reduction (SCR) of NOx emissions, is translated into a practical calculation method relating the urea-additive CO2 emissions to the consumption of urea-additive and diesel fuel.

Road specific urea-additive CO2 emission factors are derived based on a urea- additive (AdBlue) consumption of 6 vol. % (Euro V) or 3 vol. % (Euro VI) of the diesel fuel consumption, Moreover, the emission factor from urea additive is 0.238 kg of CO2 per kg of urea solution.

For the calculation of CO2 due to SCR of NOx, a Tier 3 approach is applied, as fuel consumption is calculated through COPERT for all vehicle types and categories taken into account. Urea emissions are calculated since 2008, as Euro V and Euro VI HDVs started to enter in circulation in 2008 and hence no emissions occurred before 2008.

4.18.3 Uncertainty and time-series consistency

The uncertainty of the activity data is 3% and the EF for the CO2 emissions estimation is 3%.

The time-series of the CO_2 emissions show important fluctuations. For these years an increase in emissions is recorded each year. In ***Figure 4.18*** it is seen that for 2013 there was a continues increase since 2008. In particular, in year 2023 an increase of 4.41% since 2022.

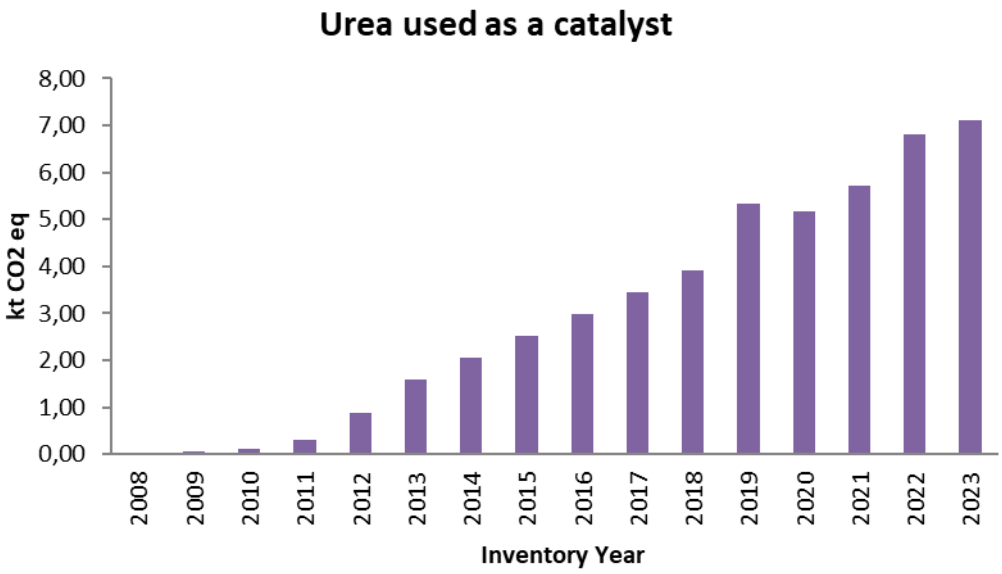


Figure 4.18 ***CO_2 emissions (in kt) from urea-based additives in catalytic converters for the period 2008– 2023.***

4.18.4 Recalculations

No recalculation was performed during this submission.

4.18.5 Planned improvements

The current submission can be considered satisfactory.

4.19 Solvent Use (CRT Source Category 2.D.3)

4.19.1 Description

Most solvents are part of a final product, e.g. paint, and will sooner or later evaporate to the atmosphere. This evaporation of solvent and other products containing volatile organic compounds represents a major source of NMVOC emissions that, once released into the atmosphere, will react with reactive molecules (mainly HO-radicals) or high energetic light to finally form CO_2. According to the IPCC Guidelines, the following applications are included in this source category:

- Paint application
- Degreasing and
- Dry Cleaning

Solvent use does not constitute a key source category. Total NMVOC emissions in 2023 accounted for 0.43% of total GHG emissions from Industrial Processes. The emissions from Solvent Use are summarized in ***Table 4.25.***

Table 4.25 NMVOC emissions (in kt) from Solvent Use for the period 1990 – 2023.

Year	NMVOC Emissions from paint application (kt)	NMVOC Emissions from Degreasing (kt)	NMVOC Emissions from Dry Cleaning (kt)
1990	20.07	4.10	0.77
1991	20.48	4.28	0.87
1992	20.90	4.51	0.97
1993	21.33	4.27	0.84
1994	24.30	4.27	0.85
1995	23.70	3.66	0.91
1996	24.20	3.73	0.88
1997	25.78	4.46	0.66
1998	26.89	4.35	0.95
1999	28.10	4.37	0.85
2000	29.30	4.92	0.89
2001	31.18	5.11	0.84
2002	33.24	3.31	0.63
2003	40.97	5.19	0.87
2004	40.57	4.57	0.73
2005	41.19	4.14	0.63
2006	42.64	4.14	0.70
2007	45.27	4.60	0.64
2008	38.88	3.37	0.61

2009	35.17	2.49	0.51
2010	38.77	0.77	0.47
2011	38.72	0.65	0.34
2012	32.05	1.23	0.30
2013	33.96	0.79	0.30
2014	34.70	0.7	0.33
2015	35.92	2.46	0.26
2016	34.19	2.23	0.27
2017	36.04	2.61	0.26
2018	36.05	3.24	0.24
2019	40.14	3.67	0.23
2020	40.57	3.88	0.22
2021	40.69	3.35	0.21
2022	40.98	3.54	0.19
2023	41.20	3.61	0.19

4.19.2 Methodology

- Concerning Paint application, emissions deriving from coating application for decorative, industrial or other applications of paint (including lacquers and varnishes and excluding glues and adhesives use) were calculated. Emissions of NMVOC associated to annual paint sales for different types of paint (assuming that 100% of sales used for coating applications) in Greece were calculated by applying Tier 1 methodology:

$$\text{NMVOC emissions} = \Sigma\ (ADi * Pi * EFj) \text{ where}$$

- ADi: Activity data for every type (i) of paint used derive from the Prodcom database of the Hellenic Statistical Authority (www.statistics.gr)
- Pi: percentage of (i) type of paint used which consumed in one of the above three (j) coating applications (decorative, industrial and other) derive from national studies.
- Efj: emissions factors for each one (j) of the three coating applications derive from EMEP/EEA air pollutant emission inventory guidebook 2016

Tier 1 methodology was used using the following EFs: 150gr/kg paint applied for decorative coatings, 400gr/kg paint applied for industrial coatings and 200gr/kg paint applied for other applications. Data from Eurostat are used for the Activity data acquisition for the whole time series regarding paints used.

- Degreasing Category presents the emissions from the cleaning process of industrial products (mainly metals) from water insoluble substances (grease, fats, oil etc). Due to EMEP/EEA air pollutant emission inventory guidebook 2016 the most common organic solvents used are: methylene chloride (MC), tetrachloroethylene (PER), trichloroethylene (TRI), xylenes (XYL).

Emissions of NMVOC associated to annual use (Product + Import - Export) of the above organic solvents were calculated by applying a combined Tier1/Tier3 methodology:

NMVOC emissions = ADxyl * EFxyl + Σ (ADi * Pi * EFi) where:

- ADxyl and ADi: Activity data for all organic solvents used derive from United Nation Statistics division (http://data.un.org/)
- EFxyl: emission factor for XYL derives from EMEP/EEA air pollutant emission inventory guidebook 2016 (Tier 1 method)
- Pi: percentage of the TRI, PER and MC (i) organic solvent used for degreasing applications derive from national studies.

Organic Solvent	*Pi*	*EF (gr/kgsolvent)*
methylene chloride (MC)	0.8	550
tetrachloroethylene (PER)	0.4	600
trichloroethylene (TRI)	0.8	850
xylenes (XYL)	1	460

- Efi: emissions factors for TRI, PER and MC (i) organic solvent derive from national studies.

- Dry Cleaning Category presents the emissions from the cleaning process of textiles (furs, leathers, etc) in order to remove contamination. Due to national studies the main organic solvents used for dry cleaning are: methylene chloride (MC), tetrachloroethylene (PER) and trichloroethylene (TRI). Emissions of NMVOC associated to annual use (Product + Import - Export) of the above organic solvents were calculated by applying a Tier3 methodology:

NMVOC emissions = Σ (ADi * Pi * EFi) where:

- ADi: Activity data for all organic solvents used derive from United Nation Statistics division (http://data.un.org/)
- Pi: percentage of the TRI, PER and MC (i) organic solvent used for dry cleaning application derive from national studies.
- Efi: emissions factors for TRI, PER and MC (i) organic solvent derive from national studies.

Organic Solvent	*Pi*	*EF (gr/kgsolvent)*
methylene chloride (MC)	0.2	550
tetrachloroethylene (PER)	0.6	600
trichloroethylene (TRI)	0.2	850

4.19.3 Uncertainty and time-series consistency

The uncertainty of the activity data is 6% and the EF for the CO2 emissions estimation is 3%. As reported in the 2006 IPCC Guidelines usually for this source category only small annual changes are expected. In 2017 a increase in emissions is presented equal to 6.07% mainly affected by the increase in paint application which plays the leading role in this category, followed by a slight

increase by 1.60% in 2018 and 1.53% for 2019. In 2022 the emissions increased by only 0.7% compared to 2021, while in 2023 an increase of 0.55% was reported compared to 2022.

4.19.4 Recalculations

No recalculation were performed this year.

4.19.5 Planned improvements

The current submissions is considered satisfactory, after the detailed recalculations performed during the 2018 submission.

4.20 Product Uses as Substitutes for ODS (CRT Source Category 2.F.1 to 2.F.6)

4.20.1 Description

According to the 2006 IPCC Guidelines there are six categories accounting for emissions from the use of ODS substitutes. In specific, emissions of f-gases are generated during the manufacturing, operation/maintenance and final disposal of the following materials/equipment:

- Refrigerating and air conditioning equipment (2.F.1)
- Foam Blowing Agents (2.F.2)
- Fire Protection (2.F.3)
- Aerosols (2.F.4)
- Solvent uses (2.F.5)
- Other applications (2.F.6)

In order to obtain a reliable estimation of f-gases emissions, the collection of detailed data for all the activities (e.g. number of refrigerators, type and amount of refrigerant used by each market label, substitutions of refrigerants that took place the late years etc.) is required. The availability of official data in Greece is limited and, therefore, in some cases the estimations presented hereafter involve the application of country specific methodologies.

In order to resolve any remaining completeness issues and given the fact that there has not been any opposite indication for the use of the PFCs in Fire Extinguishers and f-gases in Solvent Uses up to now, in September 2010 Greece has decided to use information from inventories of neighbouring countries. In specific for Solvent uses the inventory of Italy has been used while for Fire Extinguishers the inventories of Italy, Spain and Portugal have been used, on the grounds that the climatic and socio-economic conditions between Greece and these Countries are quite similar.

Emissions from Refrigerating and air conditioning equipment subcategory substitutes a key category in the Greek inventory system by level and trend assessment. Emissions from ODS in 2023 (***Table 4.26***) accounted for 49.54% of total GHG emissions from *Industrial Processes and Product Use* and for 6.28% of total national emissions (without *LULUCF*). The emissions in 2023 following the latest years present a decrement of 1.47% comparing to 2022. Despite this fact, the average annual rate of emissions' increase for the period 1995 – 2016 estimated at 28.89%. Although, the new regulations have already been applying in Greece, this category in mostly driven from the existing equipment that present high emissions during its disposal. Emissions from refrigeration and air conditioning equipment are by far the more important subcategory, contributing by 92.89% to the emissions from ODS substitutes, while emissions from fire protection are at the second place (3.39% contribution to the emissions from ODS substitutes in the 2023 inventory).

Figure 4.19 shows the contribution from each subcategory to the total emissions from ODS substitutes.

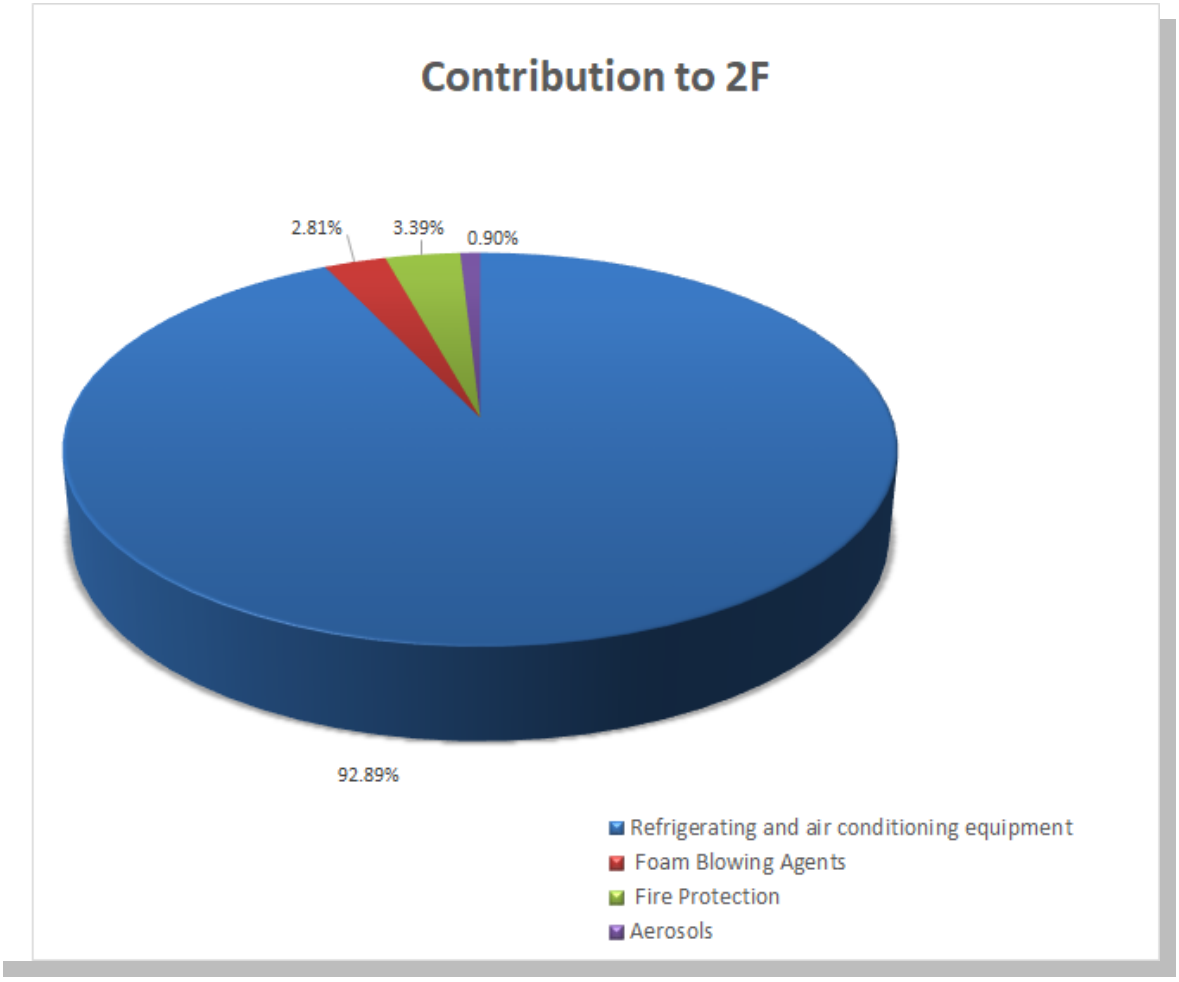


Figure 4.19 F Gases emissions distribution from ODS substitutes in 2023

Table 4.26 F-gases emissions (in Kt CO_2 eq) per gas from ODS Substitutes for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
HFC-23	NO	NO	NO	NO	NO	NO	NO	5.56	12.18	19.46	30.57	39.45	51.45	65.91	76.15	87.03	96.06	143.93
HFC-32	NO	NO	NO	NO	NO	0.03	0.22	0.73	1.46	2.46	4.80	9.26	15.19	24.45	36.35	48.92	63.61	79.93
HFC-125	NO	NO	NO	NO	NO	5.52	10.97	21.83	35.74	52.04	81.91	124.35	179.38	254.03	345.33	479.19	578.89	728.37
HFC-134a	NO	NO	NO	0.09	0.15	24.85	47.66	86.64	136.16	195.47	278.08	388.28	497.63	615.97	750.16	1,060.87	1,221.05	1,386.54
HFC-143a	NO	NO	NO	NO	NO	9.57	17.65	32.44	50.70	70.75	102.13	136.99	180.72	230.57	286.01	405.59	439.28	536.98
HFC-152a	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	3.10	57.00	90.85	98.68	117.58	148.68	157.08
HFC-227ea	NO	NO	NO	NO	NO	NO	NO	NO	NO	3.29	4.58	6.27	8.15	10.50	13.81	17.54	21.41	25.56
Unspecified mix of HFCs R600a & R1234yf	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
PFC-116	NO	NO	NO	NO	NO	NO	NO	1.84	4.03	6.44	12.12	14.95	21.09	28.37	31.56	35.16	38.15	54.00
TOTAL				**0.09**	**0.15**	**39.98**	**76.51**	**149.05**	**240.27**	**349.90**	**514.19**	**722.64**	**1010.61**	**1320.66**	**1638.04**	**2251.89**	**2607.12**	**3112.38**

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
HFC-23	156.23	159.83	185.71	164.48	184.38	186.65	151.27	5641.71	5844.57	5806.45	5559.42	5137.08	4816.27	4675.61	4558.17	4491.83
HFC-32	95.69	110.73	133.50	164.62	207.56	280.16	305.90									
HFC-125	856.94	969.30	1,162.25	1,354.22	1,622.64	1,984.60	2,141.87	147.39	128.76	119.84	100.03	88.41	81.29	76.58	73.43	70.82
HFC-134a	1,583.20	1,645.43	1,694.75	1,712.86	1,679.40	1,780.56	1,703.53	310.70	345.28	332.06	338.35	310.98	289.34	278.31	282.83	282.72
HFC-143a	603.46	641.97	744.67	776.47	848.63	851.90	878.39	2298.14	2575.87	2662.76	2661.16	2496.68	2368.00	2324.63	2299.08	2296.61
HFC-152a	169.57	172.79	178.01	180.69	185.94	176.28	176.99	1724.26	1662.88	1530.14	1378.82	1226.00	1104.45	1061.45	1040.35	1029.00
HFC-227ea	29.61	105.68	116.63	126.92	135.94	143.38	147.37	832.00	798.39	820.81	740.89	675.31	630.93	592.29	545.34	537.63
Unspecified mix of HFCs R600a & R1234yf	NO	NO	NO	NO	NO	NO	NO	178.14	179.15	180.09	181.11	182.11	183.06	183.00	164.29	121.83
PFC-116	58.07	59.26	81.94	58.92	81.30	81.78	50.08	48.80	42.63	39.68	33.12	29.27	26.91	25.35	24.31	23.45
TOTAL	**3552.77**	**3864.99**	**4297.47**	**4539.17**	**4945.79**	**5485.32**	**5555.40**	**5690.51**	**5887.20**	**5846.12**	**5592.54**	**5166.35**	**4843.19**	**4700.96**	**4582.48**	**4515.28**

The demand of A/C equipment is highly dependent on the climate conditions. Generally, the raise of the annual mead temperature and the occasional extreme heat waves increase the demand. However, in the last years the economic recession (decrease of consumers' incomes, decrease in consumer loans, credit cards etc.) plays a strong role in the market. The construction activity is another factor that also affects the demand for air conditioner equipment. The sales are also driven by the need to replace the old existing equipment with new less energy consuming products. The replacement depends on the product life, which is usually a factor of the quality and the conditions of use. It should be mentioned that in 2009 the Ministry of Development & Competitiveness (former: Minister for the Economy, Competitiveness and Shipping) motivate consumers to replace their old equipment within the framework of an action called "Changing A/C Equipment". More than 140,000 "old equipment" were replaced. Moreover, the occasionally observed increases in international oil prices, along with the recent increase in fuel consumption tax led the consumer to choose A/C equipment for heating purposes. The value of refrigerating equipment can have a positive or negative effect on demand. Usually, the competition between importing and producing companies and the competitive pricing can drive the sales of products.

The National Association of Refrigeration Importing and Trading Companies has provided, among others, information for the introduction of f-gases in the Greek market. Depending on the data availability, 1995 has been considered the f-gas introduction year for most subcategories in stationary refrigeration and air conditioning, while 1993 has been used as the first year of f-gases use in domestic refrigeration. In any case Greece is using 1995 as base year, and therefore this does not cause any problem to the time series. With regards to transport refrigeration, 2000 has been selected as the first year, based on previous expert judgement performed by the National Association of Refrigerating and Cooling Technicians.

On the basis of the same information the use of f-gases covers the whole refrigeration, mobile air-conditioning and stationary air-conditioning market. It should be noted that as regards transport refrigeration usually the import concerns already used vehicles; Therefore, the import of each year is corresponded to a 2-5 year previous manufacture.

As regards to the rest of the categories, the use of f-gases in MDIs has been in place since 1995, according to information received by the National Organization of Medicines, while emissions from foam blowing and fire extinguishers have been more recent (2001 and 1999 respectively).

4.20.1 Methodology

Refrigeration and air-conditioning

F-gases emissions are estimated based on the Tier 2a methodology described in the 2006 IPPC Guidelines. This is a bottom-up approach based on detailed equipment data and emission factors representing various types of leakage per equipment category. It should be noted that the application of the Tier 1 methodology (calculation of potential emissions based on imports, exports

and domestic consumption of each gas) and Tier 2b (calculation of actual emissions based on detailed sales data per gas and activity) is not possible for the time being, as the available information is not reported in the way required by these methodologies.

Total emissions are calculated as the sum of ***assembly*** emissions (emissions associated with product manufacturing, even if the products are eventually exported), ***operation*** emissions that include annual leakage from equipment stock in use (regardless of where they were manufactured) as well as servicing emissions and ***disposal*** emissions that include the amount of refrigerant released from scrapped systems, regardless of where they were manufactured, according to the following equation:

$$E_C = DOM \cdot CH \cdot k$$

$$\mathrm{E_O} = \left(\sum_{t_0}^{T} \left(\mathrm{DOM} + \mathrm{IMP} - \mathrm{EXP} \right)_t \cdot \mathrm{CH} \right) \cdot \mathrm{x}$$

$$E_D = \left(DOM + IMP - EXP \right)_{T-n} \cdot CH \cdot y \cdot (1 - z) - DES$$

The sources of emissions included in the category refrigeration and air conditioning equipment, are the following:

- Refrigeration
  - Residential applications
  - Other commercial applications (incl. Industrial)
  - Small commercial applications
  - Transport refrigeration
- Air conditioning
  - Split unit systems and semi-central systems.
  - Central air conditioning – Chillers
  - Other applications of central air conditioning
  - Mobile air conditioning

Regarding the activity data (number of equipment) the following should be mentioned:

- Data residential refrigeration equipment flows for the period 1993 – 2013 are provided by market surveys (ICAP 2000, 2002, 2006, 2008, 2010, 2014, 2019). The latest market survey (2019) was used in the submission of 2022 for the first time. For 2021 and 2022 emissions are estimated using the expert judgements and national/ international studies regarding the trends in this market.
- Data on the commercial and industrial refrigeration equipment flows are determined based on ElStat data. Refrigerated show cases and counters are included in the category of large commercial applications while the rest refrigeration equipment (except residential refrigeration) is considered as small commercial installations.
- Data on the number of transport refrigeration for 2000-2022 are provided by the Ministry of Infrastructure and Transport and by the Association of Motor Vehicle Importers Representatives.

- Data on the air conditioning equipment flows for the period 1993 – 2021 are provided by market surveys (ICAP 2000, 2002, 2003, 2005, 2008, 2009, 2011, 2013, 2015, 2018, 2020) and for 2023 emissions are estimated using the expert judgements and national/ international studies regarding the trends in this market. The latest market survey (2020) was used in the submission of 2022 for the first time.
- Data on the number of new vehicles are provided by the Ministry of Infrastructure and Transport and by the Association of Motor Vehicle Importers Representatives.

The National Association of Refrigeration Importing and Trading Companies (President and members) and the companies related to the sales of equipment containing f-gases, are determined **the refrigerant blends that are in the market** and **their percentage distribution** along with **f-gases penetration** for each application. More specific, the Inventory Team has been first been informed by the President of the Association of Refrigeration Importing & Trading Companies on the refrigerant blends that are in the market (or have been during the inventory timeseries). An excel form sent out to all members of the Association asking for the quantities imported, exported and sold per blend and year. Every year (n), about 50% of the companies filled and sent back the reports for the year n-2, indicating the quantities sold in national market, whether they have been obtained by the national market or imported, and exported, and also the years on which each blend has been circulated. Based on the data provided, **the percentage distribution** of each blend has been determined. Moreover, a form sent out annually, to the companies producing/importing/exporting refrigeration and air conditioning equipment in Greece. The response of the companies has been rather reluctant in a way that, for the time being, the data can be used only as indicative for incompleteness reasons. It should be noted however, that given the intrinsic complexity of the time-series and the market, the sample can be considered quite representative, and the reported information has been used additionally to the one provided by the gas importing companies. The **used blends for each application** and **f-gases penetration** derived from the information derived from the National Association of Refrigerating and Cooling Technicians in conjunction to the data provided from National Association of Refrigeration Importing and Trading Companies and the members, and the Companies related to the sales of equipment containing f-gases.

Table 4.27 Used blends for each application.

SubCategories	Refrigerant used
Refrigeration - Residential	R134a, R-600a
Refrigeration – Other commercial & Industrial applications	R134a, R404a, R407c, R507a, R23, R508b, R410a, R422a, R422d, R437a
Refrigeration – Small commercial applications	R134a, R410a,R407c
Transport Refrigeration	R134a, R404a, R410a
Air conditioning – Split units and semi central systems	R407c, R410a, R417a
Air conditioning – Chillers	R134a, R407c, R410a
Air conditioning - Other applications of central air conditioning	R407c, R410a, R417a

Mobile Air conditioning	R134a, R1234yf

The values of the basic parameters used for the estimation of emissions, as well as the type of refrigerant used in each category are based on expert judgement performed by members of the National Association of Refrigerating and Cooling Technicians, in combination with the default values provided in the 2006 IPCC Guidelines. With reference to the blends used in each application, additional information has been provided by the President of the National Association of Refrigeration Importing and Trading Companies and cross-checked by the conclusions made from the reporting of the equipment companies.

In the current submission the EF as changed in the previous year, are used. In more details in 2021 submission, a change in EFs in 2.F.1.f subcategory performed in order to include the effects of the implementation of the Regulation 517/2014 in emissions from stocks. More specifically, the implementation of 517/2014 in Greece led to a mandatory training and certification of technicians, which along with the improved installation procedures cause a reduction and even prevention of Fgases leaks. The change of the values of Emission Factors in operation emissions to depict the effect of 517/2014 regarding training, certification and improved installation procedures, are the following:

a. Chillers: Emission Factor in Operation emissions changed from 5% to 4.5%

b. Split Units: Emission Factor in Operation emissions changed from 5% to 4.5%

c. Other Applications of A/C: Emission Factor in Operation emissions changed from 10% to 9.5%

All the above-mentioned information regarding the communication and meetings with experts, such as with the Association of Refrigerating and Cooling Technicians, has been archived to the Centralized File of the Inventory. The Inventory team come to close collaboration (meetings and/or Skype and/ or teleconference meeting, telephone communications) with experts on an annual basis or more frequently if needed. Thus, all the information is updated and all the data are verified over the years. In addition, the inventory team during the annual meeting with the experts, collaborate with members from the National Association of Refrigeration Importing and Trading and National Association of Refrigeration and Cooling Techniques and verify, evaluate and revise, as necessary, the parameters' values (percentage distribution of each blend, type of refrigerant used in each category, possible trends used, etc) used in estimating emissions, in accordance with the default values provided in the 2006 IPCC Guidelines.

The structure of the emissions from each sub-source for 2023 is presented in ***Figure 4.20***.

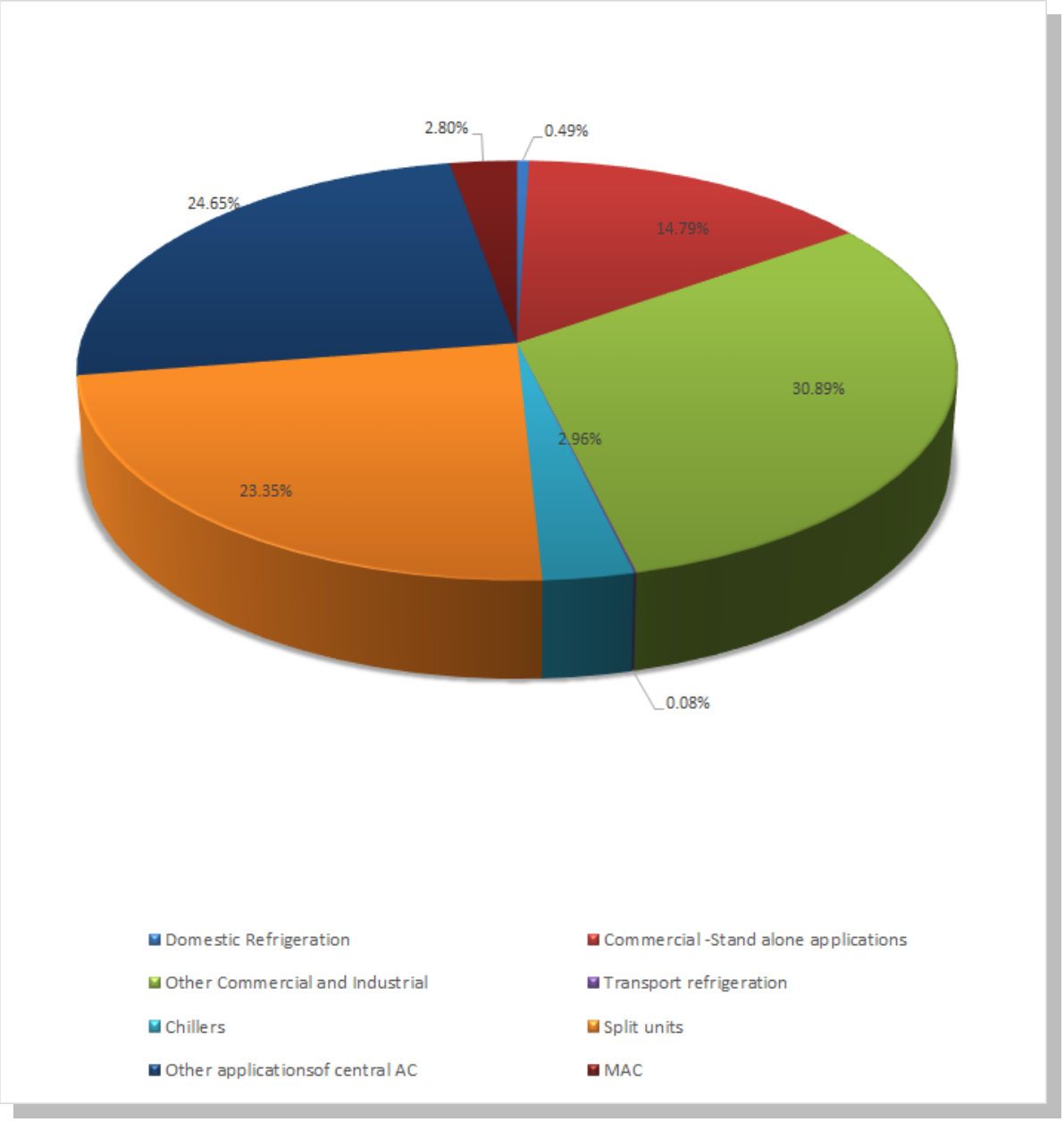


Figure 4.20 Contribution of each sub-source for 2.F.1 for 2022

Total F-gases emissions from the above-mentioned applications are presented in ***Table 4.28*** for the period 1993-2023.

According to the recent ICAP survey, the following points are highlighted:

- the production sector of air conditioning equipment in Greece includes very few companies, contrary to the companies that import such equipment,
- the total domestic production of air conditioning equipment has been greatly reduced in recent years.

- The domestic market of Chillers has been decreased 10.20% in 2017. Sales of central ACs, also present significant decrement. On the other hand, fan coils market moved upwards to 18,800 units in 2017.
- Sales of Split units amounted to 244,400 units in 2017 and showed an annual increase of 8.6% compared to 2016. Nearly similar growth was also presented in semi-centralized AC systems in the same period (+ 8.2%).
- The decrement of emissions MAC subcategory occurred due to the significant decrement in the sales of new cars in Greece following the the financial recession and new direct and indirect taxes in the last years regarding the new cars.

Despite the decrement in the sales of AC equipment mainly after the economic recession, evaluating the current market conditions in Greece, it is estimated that prospects for the AC industry are more favorable than the recent past years.

Table 4.28 F-gases emissions (in kt CO_2 eq) from refrigeration and air conditioning equipment for the period 1993 – 2023

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Domestic refrigeration	0.09	0.15	0.23	0.35	0.53	0.69	0.86	1.01	1.13	1.24	1.31	1.37	1.43	1.44	1.52	8.96
Commercial-Stand Alone Appl.	0.00	0.00	1.09	2.73	5.88	9.95	12.97	17.57	26.53	35.70	53.15	75.54	100.67	129.77	165.77	200.53
Other Commercial- Industrial Appl.	0.00	0.00	35.07	64.94	126.50	202.18	285.30	395.37	510.20	640.15	795.21	946.59	1346.75	1421.71	1757.17	1935.89
Transport Ref	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.86	1.56	2.28	2.98	3.75	4.63	5.68	7.44
Chillers	0.00	0.00	0.07	0.15	0.30	0.72	1.57	2.88	6.61	12.74	20.33	29.54	39.54	50.14	61.74	74.80
Split-Units	0.00	0.00	0.23	0.45	1.07	2.19	4.34	11.41	26.74	36.87	50.10	67.26	92.80	121.90	153.84	188.75
Other Applications of Central AC	0.00	0.00	0.12	0.30	0.68	1.86	4.22	10.60	23.38	50.57	94.99	143.50	192.49	244.51	298.92	357.06
MAC	0.00	0.00	3.13	7.55	14.05	22.66	37.33	70.37	115.61	158.91	201.63	258.46	312.06	366.57	414.37	474.16
TOTAL	**0.09**	**0.15**	**39.95**	**76.48**	**149.01**	**240.24**	**346.58**	**509.58**	**711.05**	**937.73**	**1,218.995**	**1,525.236**	**2,089.489**	**2,340.670**	**2,858.99**	**3,247.59**

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Domestic refrigeration	12.48	24.01	35.91	41.51	41.95	41.49	42.77	41.83	35.67	24.72	24.74	25.87	24.04	20.50	22.71
Commercial-Stand Alone Appl.	227.59	274.66	341.21	373.30	445.50	514.60	514.18	553.86	566.30	595.60	655.26	667.67	642.92	623.85	613.65
Other Commercial- Industrial Appl.	2011.28	2220.83	2231.20	2340.01	2371.42	2294.02	2217.51	2022.10	1978.59	1716.79	1553.59	1465.43	1386.84	1303.38	1264.22
Transport Ref	8.19	8.81	8.51	8.07	7.81	7.51	7.25	6.42	5.39	4.50	3.45	3.37	3.35	3.37	3.40
Chillers	88.09	99.82	120.19	137.49	148.27	157.66	159.53	162.06	161.44	160.13	154.48	139.08	132.96	124.80	123.62
Split-Units	224.75	262.46	297.36	339.90	377.61	417.26	517.29	664.74	604.74	676.42	760.03	859.03	928.17	985.23	1,030.18
Other Applications of Central AC	402.50	478.88	611.94	823.37	1,195.56	1,243.49	1,380.85	1,626.64	1,714.79	1,712.82	1,394.23	1,136.65	1,059.58	1,039.89	1,037.99
MAC	546.53	570.63	540.81	515.06	507.01	485.73	451.41	405.04	366.98	289.44	209.12	159.15	137.39	118.30	98.82
TOTAL	**3,521.42**	**3,940.10**	**4,187.12**	**4,578.71**	**5,095.14**	**5,161.77**	**5,290.79**	**5,482.70**	**5,433.88**	**5,180.43**	**4,754.90**	**4,456.24**	**4,315.24**	**4,219.32**	**4,194.60**

With regards to Residential Refrigeration. according to the data provided by ICAP SA. the majority of the equipment concerns small capacities (lower than 150 L). Other important categories include combinations of refrigerators and freezers characterized by individual external doors. residential refrigerators with compression of a capacity above 340 L and also refrigerators of medium capacity (between 250-340 L). Based on the data provided by the equipment companies the majority of the equipment does not contain R-134a (R600 is being used instead). Especially for the in country produced equipment. the one Greek company active in this area has affirmatively reported the non-use of f-gases in domestic refrigeration equipment. This has been also crosschecked with an information material provided online by the Greenpeace's national website.

With respect to Commercial and Industrial equipment. small applications refer to stand alone equipment mainly used in mini markets and other food trade. private and public companies. restaurants. etc. The main blends used are R134a. R407c and R410a. after 2001. It should be mentioned that R410a is used in new equipment only. while the other two gases are also used in retrofit. for the replacement of R-12 and R-22 respectively. Other commercial and industrial applications refer to refrigerants used for chemical and food production processes. With regards to Industrial applications. penetration is considered quite limited due to the important use of NH_3 as a refrigerant (especially in chemical industries aka fertilizer companies). The blends used in this case vary importantly and are increased in the recent years (R422a. R422d and R437a have been all reported to be used after 2006). It should be noted that the last three cases the blends are used only in retrofit and therefore do not have emissions from assembly. R23 and R508b are also reported in low quantities. being used in very low temperatures (deep freezing applications in hospitals).

The trend concerning A/C equipment refers to the movement of the Greek market based on the production. sales. imports and exports of the units. However, emissions in each year concern the use of the corresponding equipment. and therefore, the effects of these facts are made visible in the following years of the inventory.

In general. 2.F.1 category and the observed fluctuations can be attributed to the high inertia of 2F category in total (equipment bought in one year continues to emit gases in the years to follow up to its final disposal).

Regarding the recycling amount of f-gases in refrigeration and air-conditioning. the data provided by the Appliances Recycling SA. Thus. the amount of F-gases that is recycled and reported in CRT Tables is not an estimate. but it is the activity data that were reported by the company that performs the recycling (plant specific activity data). The communication with Appliances Recycling SA is documented in appropriate forms (in Greek) which has been archived to the Centralized File of the Inventory. as required by the internal QA/QC system. We also perform QC checks to these data. e.g. comparison with IPCC default recovery rates. time series consistency. consultation with experts from the Ministry of Environment and Energy who oversee this sector. etc.

Foam blowing agents

Emissions from foam blowing refer to emissions from hard foam production. The implemented methodology is described by the equation 7.7 of the 2006 IPCC Guidelines:

Emissions from closed-cell foam = [(Total HFCs and PFCs used in manufacturing of new closed-cell foam in year t) · (first-year Loss emission factor)]
+ [(Original HFC or PFC charged blown into closed-cell foam manufacturing between year t and year t-n) · (annual loss emission factor)]
+ [(Decommissioning losses in year n)-(HFC or PFC destroyed)

In order to perform the estimation of the emissions. data have been collected using information by the questionnaires filled by the four industries of the sector for this reason. According to the information received by the respective companies the Greek market is mainly covered by the products produced in Greece. In general. the industries reported that they do not make any use of PFCs. while one of the industries has also reported the use of other (proprietary) Blowing Agents (PBA) than HFCs. The consumption of foam products containing HFCs has begun in Greek market in 2001 and all the HFCs used concerns the manufacturing of XPS panels. HFC-134a has been used for the period 2000-2001 by one plant. while all the other plants of the sector use HFC-152a. The observed fluctuation in the emission trend (***Figure 4.21***) is due to the different operation periods of the companies. More specifically one of the companies started the use of HFCs in 2001 until today. while a second company started in 2003 and still reported the use of HFCs. A third company has reported use of HFCs only during the period 2006-2009 and the last company has reported no use of HFCs at all since it uses PBAs. From 2004 the use of HFCs decreased from another company since it also uses PBAs since then.

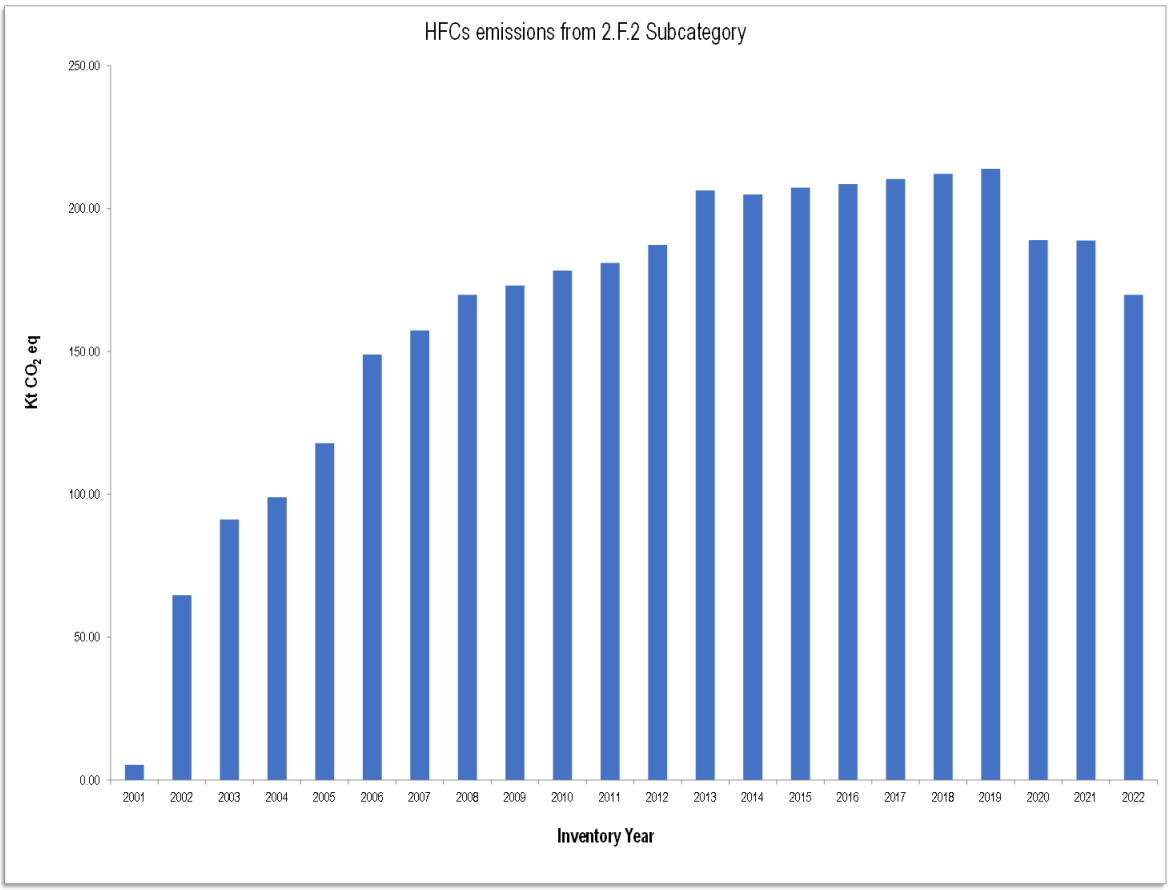


Figure 4.21 HFCs emissions from 2.F.2 Subcategory for the period 1990 – 2023.

From the four companies that report in the Greek system only one has mentioned. apart from XPS production. imports of XPS foams (average of 2.6 % of company's sales). In this case the HFCs emitted from the imported products have been already taken into account in the calculations performed in the previous years. The other companies have explained to the Inventory Team that they are either concentrated only on production or that they do import products that. however. do not contain HFCs. In the 2012 in Country Review the ERT have recommended to continue to collect further information on imports of foam products containing HFCs. In line with this the Inventory Team has tried to contact the PanHellenic Association of Insulating Companies. However. the Association does not provide the required data. probably due to the lack of such data. The inventory team in order to be consistent with the 2012 improvement plan and the ERT recommendations. in 2014 conducted for the first time all the members of the Associations. asked them to fill an excel form with the amount of imported and exported quantities of foam products containing HFCs. Despite the fact that the respondence was not very high the Inventory Team keep sending them the excel forms and try to inform them and encourage them. in order to overcome their confidentiality issues. Over 30% of the members. keep responding annually. thus. the data can be used only as indicative for incompleteness reasons. However. the members that responded reported that they either they do not import foam products because they fulfil their needs from the Greek market (products produced in Greece that have been counted in the inventory) or they import

foam products free of HFCs' which contains other (environmentally friendly) gases such as air as cell gas. It should be noted that given the intrinsic complexity of the time-series and the market. the sample can be considered quite representative and the reported information has been considered adequate by the Inventory Team. Thus, the imports of foam products in Greece are calculated from the reported data from one of the companies which apart from producing also mention imports of foam products containing HFCs. In addition. the PanHellenic Association has informed the Inventory team that even though the respond ratio does not cover all companies. it is representative of the importing foam products as the responders have the biggest market share in Greece. However. the inventory team makes a big effort every year to have a personal contact with every member of the association trying to increase the respond ratio. In addition. the Association and the producing companies have been also reassured the Inventory team that most of the equipment that are used in Greece are covered from the domestic production and the small quantities that may imported are not containing HFCs. This is an expert judgement that also the responders have reported.

Disposal emissions are not described as according to Table 7.6 of the 2006 IPCC Guidelines XPS/ HFC-134a& HFC-152a, considered to have **50 years lifetime** and this type of emissions introduced in the system in 2001. Thus, the notation key 'NO" has been reported in the disposal emissions of CRT.

Table 4.29 HFCs emissions (in kt CO_2eq) from foam blowing agents for the period 1995 – 2022

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
First Year Emissions (HFC-134a)	2.12	7.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.04
Annual Emissions (HFC-134a)	0.06	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.32
First Year Emissions (HFC-152a)	2.07	37.31	47.44	36.85	37.17	45.51	35.94	32.29	23.67	19.26	14.63	13.25
Annual Emissions (HFC-152a)	1.03	19.69	43.41	61.83	80.42	103.17	121.14	137.28	149.12	158.75	166.06	172.69
TOTAL	**5.28**	**64.69**	**91.13**	**98.96**	**117.87**	**148.97**	**157.36**	**169.86**	**173.07**	**178.30**	**180.98**	**187.30**
Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	
First Year Emissions (HFC-134a)	28.86	25.94	26.41	25.96	25.91	25.93	25.91	0.00	0.00	0.00	0.00	
Annual Emissions (HFC-134a)	1.18	1.96	2.75	3.53	4.31	5.09	5.86	5.86	5.80	5.51	5.23	
First Year Emissions (HFC-152a)	2.40	2.07	2.15	2.10	2.03	2.03	2.02	1.98	1.97	1.96	1.94	
Annual Emissions (HFC-152a)	173.89	174.92	176.00	177.05	178.06	179.08	180.09	181.08	181.03	162.32	119.89	
TOTAL	**206.32**	**204.89**	**207.302**	**208.64**	**210.30**	**212.13**	**213.88**	**189.51**	**188.80**	**169.80**	**127.06**	

Fire protection

According to the 2006 IPCC Guidelines. emissions should be estimated using the following equation:

Emissions = Annual sales of HFCs/PFCs for Fire Protection
– (HFCs/PFCs used to Charge new fire protection equipment
– HFCs or PFCs originally used to charge retiring fire protection equipment)

Although it is good practice to use the above mentioned equation. data in Greece are very scarce and the specific methodology could not be implemented. However. in order to improve the completeness of the inventory. a country-specific estimation of the emissions has been performed. based on the assumption that the use of HFCs in fire equipment in Greece is similar to the one of other Mediterranean countries (Italy. Portugal. Spain). taking into account the country's population.

More specifically the assumption made concludes that since 1999 the use of HFC-227ea for fire protection equipment has been made, since this is the Fgas used in Greece. This fact has been also confirmed from the current data introduced in the web platform of the Ministry of Environment "Maintenance and monitoring F-gases and ODS". However, it should be noted that for the time being the specific data along 2F category can be used for QA reasons and not as basic data resource (Please also refer to ch. 4.20.5).

The estimated emissions are presented in ***Table 4.30***.

This was confirmed by the National Association of Refrigerating and Cooling Technicians. For that reason, we plan for the next submission to analyze the registry data, especially the bulk input – outputs.

Table 4.30 HFC-227ea emissions (in kt CO_2eq) from fire protection equipment for the period 1999 – 2023

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
HFC-227ea	3.29	4.58	6.27	8.15	10.50	13.81	17.54	21.41	25.56	29.61	105.68	116.63	126.92
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	
HFC-227ea	135.94	143.38	147.37	151.07	154.23	160.74	159.04	157.58	159.20	159.32	152.84	153.21	

Aerosols

More aerosol packages contain hydrocarbons as propellants. but in a small fraction of the total HFCs and PFCs may also be used as propellants or solvents. Emissions from aerosols usually occur shortly after the production while 100% of the chemical is emitted. According to 2006 IPCC Guidelines. the 5 main sources of aerosols are:

- Metered Dose Inhalers (MDIs)
- Personal Care Products
- Household Products
- Industrial Products and
- Other General Products

Emissions are estimated using the following equation:

- Emissions in year t = [(Quantity of HFC and PFC contained in aerosol products sold in year t) · (EF)]
- + [(Quantity of HFC and PFC contained in aerosol products in year (t-1)] · (1 – EF)]

Data derive of the National Organization of Medicines and the Hellenic Aerosol Association. while plant-specific questionnaires have been sent to all the known private companies of the sector. based on information received by the President of the Hellenic Aerosol Association. The characteristics of the categories can sum up to the following:

Regarding MDIs:

- The use of HFC-134a in manufactured and imported metered dosed inhalers is quite common. Most of the emissions concern imported material. while there are three MDIs brands that have been produced in the country.
- According to the information received by the National Organization of Medicines. the quantity of HFC-134a by piece oscillates between 25 and 75 mg. while the usual quantity is between 47-55 mg.
- The assumption of the total emission of the HFC-134a during the first year after sale has been made. This assumption is in line with the 2006 IPCC Guidelines.

As regards to other aerosol products:

- there is only one plant that has reported the use of HFC-134a. The respective manufacturing process covers the inventory years 2005-2016. The plant has also reported the production. exports and zero imports of the respective products (products that contain HFCs) for all the years of the time-series. In 2011 the plant has informed the inventory team on the average actual charge per piece (70 g/piece). This information in combination with the production and export statistical data is considered more precise than the previous methodology (derivation and use of production/consumption rate).

Emissions from this category can be viewed in ***Table 4.31***.

Table 4.31 HFC-134a emissions from Aerosols/MDIs (in kt CO_2 eq) for the period 1995 – 2022

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
HFC-134a Emissions	0.029	0.035	0.032	0.032	0.033	0.033	0.037	0.035	0.031	0.033	26.987	96.072	70.455	105.711	64.817
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
HFC-134a Emissions	62.440	44.155	43.844	40.484	41.377	41.340	41.630	41.238	40.982	41.046	40.876	40.644	40.569	40.46	

Emissions in this subcategory are emissions from MDIs and one aerosol product. The increment observed in the MDIs emissions is important in the recent years. mainly due to the inclusion of new MDIs brands in the recent years. The observed fluctuation in the emissions can attributed mostly to the aerosol emissions. Thus. the peak in emission trend in 2005 is due to the fact that the production of aerosol product began in 2005. The variation in the emission trend between 2005 and 2008 can be attributed to the fluctuation in the production and export levels of 2005-2008 in aerosol product that affect the consumption. In 2009 to 2012 emissions experience a strong decline which is attributed to the corresponding decrease of aerosols being sold. Moreover, the decrease in the production of aerosol product was almost 25%. From 2011-2023 the emissions were not present serious fluctuations.

4.20.2 Uncertainty and time-series consistency

The uncertainty related to emissions from ODS substitutes is generally characterized by high values. In order to improve the estimation. the uncertainty has been estimated for each subcategory separately. while the category's uncertainty value is the combination of the individual estimations.

For the refrigeration and A/C equipment (CRT 2.F.1) the activity data uncertainty has been estimated at 100% whereas an EF uncertainty of 150% is used. due to the fact that the emission factors are selected based on expert's opinion (National Association of Refrigerating and Cooling Technicians) but being in the default range suggested by the 2006 IPCC Guidelines.

In the rest three categories (foam blowing agents. aerosols and fire protection) the uncertainty associated is quite lower. More specifically. in the foam blowing agents subcategory (2.F.2) the uncertainty values suggested by the 2006 IPCC Guidelines have been used. Therefore. activity data uncertainty is at about 40%. which is the proposed value for regional estimates. As regards to the uncertainty associated with the emission value. the value of 50% has been chosen. mainly because the default values have been chosen while no data are available in order to develop country specific values. As regards to aerosol products. the activity data derive from a National Organization and the estimated uncertainty value used is at 15%. whereas the emission factor used has been characterized by a typical uncertainty of 5%. It should be noted that the National Organization of Medicines provided the inventory team with detailed data (brand name. charge and consumption per year) of MDIs sold per year. Finally in the Fire Protection the uncertainty of the activity data

amounts to 60%. accounting for the absence of data. while the EF used is the default one and therefore is characterized by an uncertainty of 10%. It should be noted that even though the activity data in the 2.F.3 category are based on assumptions. the countries have been used so as to have common characteristics with Greece with respect to socioeconomical. geographical and climate conditions.

As regards to time-series consistency. the methodology used is the same for the whole time series. while the main data providers remain also the same.

In ***Figure 4.22*** the trend of 2.F.1 category is presented. As regards the chart. the general trend is increasing. However. the latest years (2017-2023) emissions present a small decrease. More specific, for the year 2023 a decrement of 5.87% from 2020 emissions was presented, due to the implementation of the new regulation in this sector.

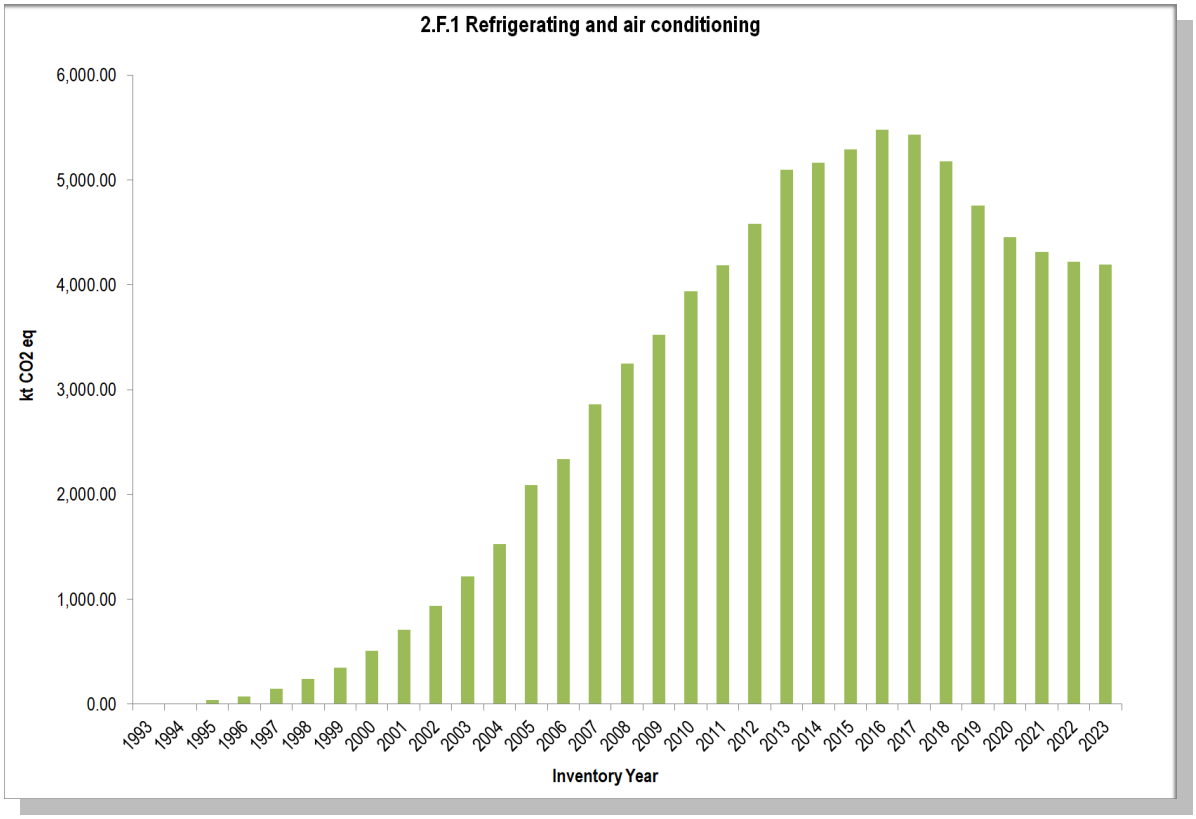


Figure 4.22 HFCs emissions from 2.F.1 category for the period 1990-2023 (in kt CO_2 eq)

In **Figures 4.23** and **4.24**. the trend of each subcategory is also presented.

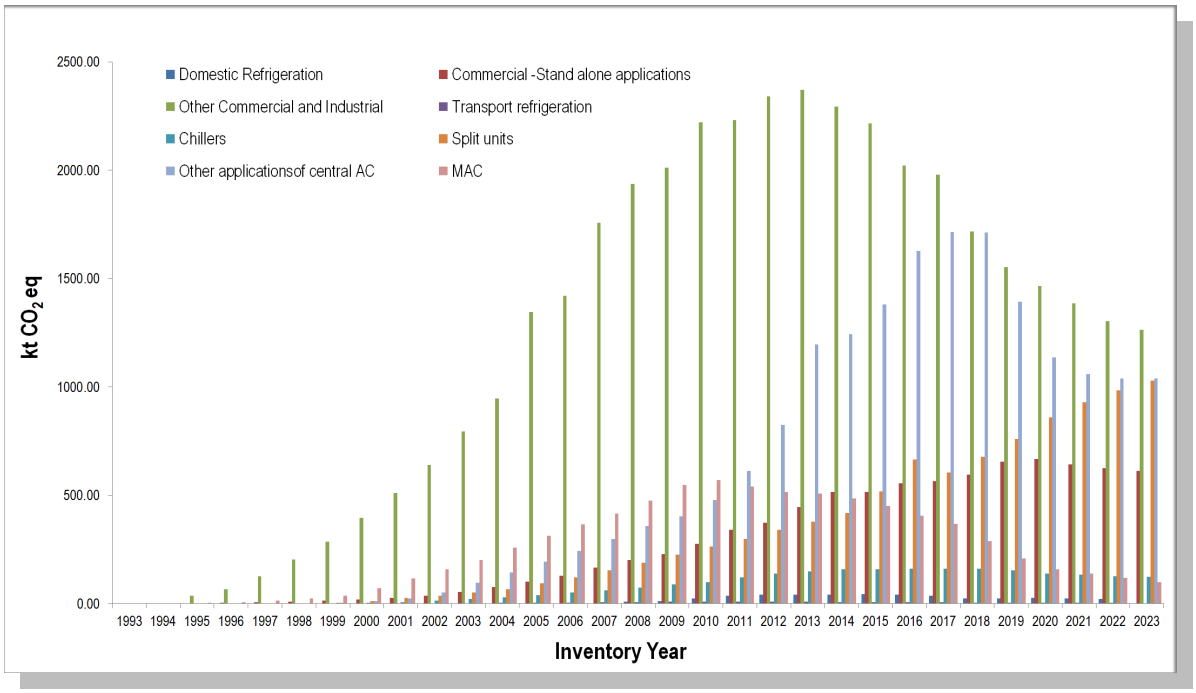


Figure 4.23 HFCs emissions from Refrigeration and A/C equipment for the period 1990-2023 (in kt CO_2 eq)

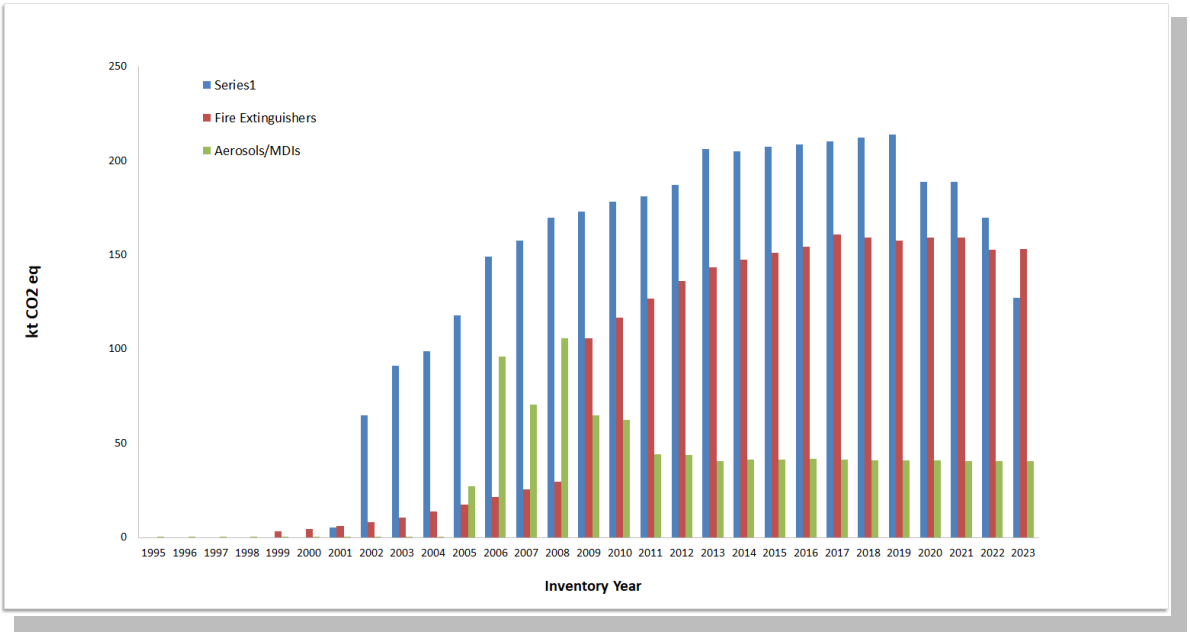


Figure 4.24 HFCs emissions from Foam blowing. Fire extinguishers and Aerosols/MDIs for the period 1990-2023 (in kt CO_2 eq)

Regarding **Figure 4.23** in each subcategory the trend is similar to the general trend (**Figure 4.22**). Production and import levels in 2011-2023 show reductions in some subcategories. which is attributed to the financial recession. however. due to the high inertia of the Sector (equipment bought in one year continues to emit gases in the years to follow up to its final disposal) this is not fully depicted in the emissions. However, in some cases (chillers. split units. mobile A/C) in 2018 production and imports have either slightly increased or are on the same levels with 2015. In addition. the implementation of new regulation for Fgases and the entrance of alternative Fgases with lower GWPs have cause a decrement in the total trend. One trait that is also important is that part of the equipment has reached its lifetime and therefore is considered to be disposed. The recycling amount of gases. according to the gathered data is quite low. this means that the increase of emissions can attributed also to the disposal procedures in some subcategories. At the same time however, this will lead to their removal from the next year and therefore the total effect is quite counterbalanced.

Figure 4.24 refers to emissions from the other subcategories of the ODS substitutes sector. Concerning the MDIs/aerosol emissions. although the increment in the MDIs emissions is important in the recent years. mainly due to the inclusion of new MDIs brands in the recent years. the total trend is a decreasing one mainly due to aerosol emissions. The observed fluctuation in the emissions can also be attributed to the aerosol emissions. Thus. the peak in emission trend in 2005 is due to the fact that the production of aerosol product began in 2005. The variation in the emission trend between 2005 and 2008 can be attributed to the fluctuation in the production and export levels of 2005-2008 in aerosol product. In 2009 and 2010 emissions experience a strong decline which continues in 2011 – 2018 and attributed to the corresponding decrease of aerosols being sold. As regards to emissions from foam blowing. the observed fluctuation is due to the fact that there are only three companies using HFCs and the trend depends on the substitution of HFCs with other blowing agents and on the different year of first use of HFCs for the production process. It can be observed in any case that the trend was a increasing one until 2013 with a slight increament in 2015 and 2017.

4.20.3 Source-specific QA/QC and verification

Source specific QA/QC procedures have been performed whenever available. However, it is important to note that in most cases this is not feasible due to the absence of official data or even data sources. The estimation using data from different sources has been feasible only in the case of aerosols and MDIs. since data have been collected by the National Organization of Medicines and private pharmaceutical companies as well. enabling the inventory team to perform cross-checking procedures. Also. the Hellenic Aerosols Association has provided a gross estimation of the HFCs level used that is in line with the plant specific information. enabling the inventory team to draw the conclusion that this subcategory is complete.

Other QA/QC procedures include the examination and verification of the trend. This has been performed and the results have been already presented in the previous paragraph (4.14.3). As it can

be concluded from the previous. the trend is not easily cross-checked due to the high inertia of the sector (the input data of each year are responsible for the emissions in the following years).

Additional QA/QC procedures involved the update of the working files. This has been performed and checked in the internal qa/qc procedures of the Inventory System and various errors have been corrected. The new files are considered to be completer and more user-friendly, whereas default values are provided for the Efs so as to additionally check the expert judgments.

4.20.4 Recalculations

In the current submission no recalculations have been performed.

4.20.5 Planned improvements

The Ministry of Environment and Energy recently launched a web platform “Maintenance and monitoring F-gases and ODS”. which aims to serve as a tracking tool and a database for users of F-gases and ozone-depleting substances to register their regular checks of maintenance refilling records. and for F-gas traders to register their transactions from 2019 onward (no historical data will be available on the platform) under the new Greek regulation on F gases. However, for the time being until all users and traders are able to populate this database with information on the use and trade of F-gases and ozone-depleting substances. the inventory team will continue using ICAP surveys to obtain data on residential refrigeration and air-conditioning equipment flows. following the recommendations of ERT (In country review 2019).

Following the recommendations of ERT the inventory team will use in the next submissions the platform to perform QC checks on data obtained through ICAP surveys, whenever the platform became functional.

4.21 Electrical equipment (CRT Source Category 2.G.1)

4.21.1 Description

The use of SF_6. as dielectric. in the transmission and distribution system of electricity. is considered as the main source of SF_6 emissions. Emissions arise in cases of leakages and during the maintenance of sub-stations and circuit breakers. especially when the equipment is old.

4.21.2 Methodology

In the context of the present inventory. emissions are estimated on the basis of information provided by PPC regarding losses in the transmission and the distribution system. The data provided cover the period 1995 – 2021. Emissions estimates are being performed on the basis of the quantity of SF_6 consumed during the year. by the Directorate of Strategy and Planning of the PPC. According to the information received by the Public Power Corporation (PPC), the methodology is the same for the reported emissions from both transmission and distribution activities and it actually refers to direct measurements of the SF_6 used to fill in any escape of the gas. The measurement procedure involves the weighting of the compressed SF_6 cylinder before and after the filling of the equipment. The difference in the weight corresponds to the kg of SF_6 that has escaped (and therefore needed to be re-filled). PPC has kindly informed the inventory team that in 2009 a new SF_6 mass-flow meter has been purchased in the department of Distribution in order to ensure the higher accuracy of the weighting. As regards to the rest of the emission. namely for the years 1990 – 1994. they are estimated (by the inventory team) by means of a linear extrapolation.

SF_6 emissions from electrical equipment are presented in ***Table 4.32***. Emissions in 2022 have been increased by 66.74% from 1990. The contribution of emissions from electrical equipment in total emissions (incl. & excl. LULUCF) is insignificant (lower than 0.00 % for the whole time-series).

Table 4.32 SF_6 emissions (in kg) from electrical equipment for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
SF6 emissions	3.02	3.11	3.21	3.30	3.39	3.53	3.62	3.67	3.71	3.81	3.92	4.00	4.18	4.18	4.39	6.35	8.23
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
SF6 emissions	9.75	7.40	5.17	6.04	5.29	5.20	5.31	5.07	5.22	5.36	5.16	5.09	5.07	5.09	5.02	5.03	5.05

The emissions refer to the escape of the gas due to old. used insulating parts of equipment (mainly gaskets) and. far more rarely. to a failure of the system. In the first case the insulating parts have to be changed. In the second case. the SF6 has to be removed in pressurised cylinders and then be re-filled to the equipment (after the fixing of the latter). Any fluctuation to the time-series depicts the maintenance issues that have risen. according to the information received from PPC. in the particular year. In general fluctuations are more intense in the Transmission system (375kg in 2007 versus 280 kg in 2008). The contact persons in the Transmission system have indicated that many

times experience is used as a driver and, therefore, a particular type of gasket that has been reported for unsuccessful insulating operation has been replaced in the systems. leading to a decrease of the escaped SF6 in the next year.

4.21.3 Uncertainty and time-series consistency

The uncertainty concerning the activity data is estimated at 50%. Regarding the EF. the estimated uncertainty 20% and is close to the default one suggested in the 2006 IPCC Guidelines.

The time-series is in general consistent. since the activity data is collected by the same provider for all the inventory years. apart 1990-1994 where the linear extrapolation method has been used.

Any fluctuation to the time-series depicts the maintenance issues that have risen in the particular year as has been analytically explained above.

4.21.4 Source-specific QA/QC and verification

For the time being the available data do not permit the implementation of any source-specific QA/QC procedure. QA/QC verification could be performed using information of the GIS providers in Greece; however, the issue is quite complicated because the filling of new equipment may be performed from different companies than the ones that cover the filling of equipment in use. The total quantities are only available by PPC and this is why the verification from external sources is not easy to be performed.

For the time being. all the available information is kept in the Input File of the inventory. according to the Greek QA/QC plan.

4.21.5 Recalculations

In the current submission no recalculations have been performed.

4.21.6 Planned improvements

There are no planned improvements for this category for the time being.

4.22 N_2O from Product Uses (CRT Source Category 2.G.3)

4.22.1 Description

Evaporative emissions of nitrous oxide (N_2O) can arise mainly by:

- Medical applications and
- Use as a propellant in aerosol products.

According to 2006 IPCC Guidelines it is *good practice* to estimate and report N_2O emissions from these sources.

N_2O for anaesthetic use is supplied in steel cylinders containing a minimum of 98 percent N_2O. N_2O is used during anaesthesia for two reasons: a) as an anaesthetic and analgesic and as b) a carrier gas for volatile fluorinated hydrocarbon anaesthetics such as isoflurane, sevoflurane and desflurane.

On the other hand, N_2O is also used as a propellant in aerosol products primarily in food industry. Typical usage is to make whipped cream, where cartridges filled with N_2O are used to blow the cream into foam.

N_2O emissions from Product Uses in 2023 (***Table 4.33)***, account for 1.48% of total GHG emissions from *Industrial Processes*. N_2O emissions from Product Uses does not constitute a key source category.

Table 4.33 summarizes the N_2O emissions from medical applications and use as a propellant in aerosol products.

Table 4.33 N_2O emissions (in kt) from Product Uses for the period 1990 – 2023.

Year	N_2O Emissions from medical applications (kt)	N_2Oemissions from use as a propellant in aerosol products (kt)
1990	0.23	0.22
1991	0.23	0.22
1992	0.23	0.22
1993	0.23	0.23
1994	0.24	0.23
1995	0.24	0.23
1996	0.24	0.23
1997	0.24	0.23
1998	0.24	0.23
1999	0.24	0.24
2000	0.24	0.24
2001	0.25	0.24
2002	0.25	0.24

2003	0.24	0.24
2004	0.24	0.24
2005	0.25	0.24
2006	0.25	0.24
2007	0.25	0.24
2008	0.25	0.24
2009	0.25	0.24
2010	0.25	0.24
2011	0.25	0.24
2012	0.25	0.24
2013	0.25	0.24
2014	0.24	0.23
2015	0.24	0.23
2016	0.24	0.23
2017	0.24	0.23
2018	0.24	0.23
2019	0.24	0.23
2020	0.24	0.23
2021	0.24	0.23
2022	0.23	0.22
2023	0.23	0.22

4.22.2 Methodology

The inventory team in order to provide emissions for these source categories proceeded as follows:

1. The inventory team started by investigating the NIRs and ERT audit reports of other Annex I parties.
2. The ratio of N_2O emissions per population (ktN_2O/1000s capita) for a cluster of Annex I parties was computed. Four European countries were selected: Italy and Spain (which have similarities with Greece as concerns climate etc), Austria and Netherlands (in order to be conservative in the estimation of emissions).
3. The mean value of the above mentioned ratios was calculated.
4. By using the population of Greece as a driver (activity data) and the above calculated ratio as “Emission factor”, the emissions for the whole time series were estimated.

4.22.3 Uncertainty and time-series consistency

The uncertainty of the activity data is 5% and the EF for the CO_2 emissions estimation is 5%. The methodology used is based on calculation of EFs from other countries and the activity data include population data as provided by EUROSTAT.

Figure 4.25 presents the changes in emissions which are in accordance with the changes in population of Greece. In 2011 and 2012 the emissions are stable while in 2013 there was a decrease in emissions equal to 0.54% since 2012. In 2014 the emissions also decreased by 1.23% compared to 2013 levels and in 2015 a decrease equal to 0.63% appeared in comparison with 2014. Finally, in 2023 there was a decrease of -1.24% in emissions compared to 2022 levels.

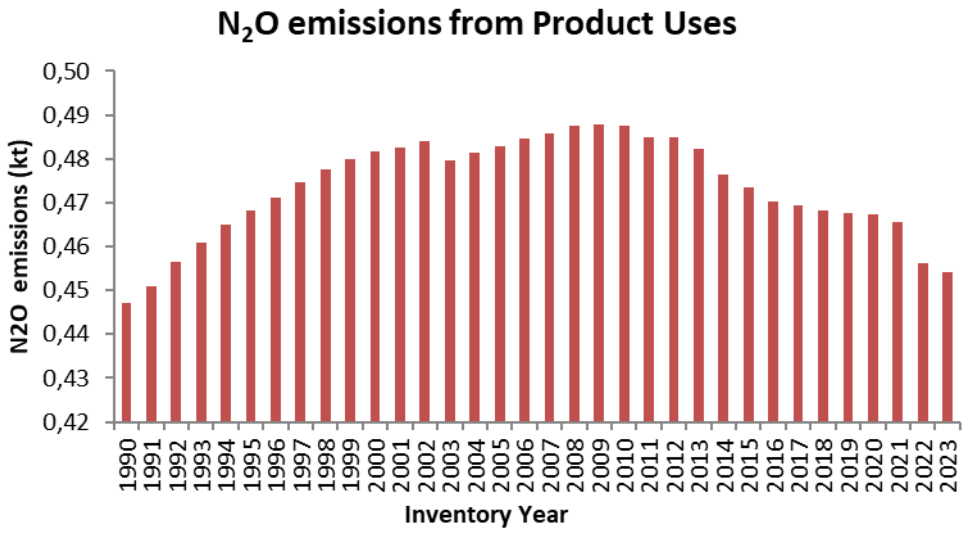


Figure 4.25 ***N_2O emissions (in kt) from Product Uses for the period 1990 – 2023.***

4.22.4 Source-specific QA/QC and verification

In absence of other data availability, the QC tests include the annual update and double check of the population data provided by ElStat and EuroStat. The data provided by Eurostat are available for the whole time series. It should also be mentioned that data availability from other sources, such as literature review, studies, etc. is limited, making more difficult the emissions estimation with higher tiers. Activity data are considered the population of Greece for the relevant years.

4.22.5 Recalculations

No recalculations have been performed during this submission.

4.22.6 Planned improvements

The inventory team is in contact with two different bodies for N2O use in anaesthesia and aerosol cans, namely the Hellenic Department of the European Society of Regional Anaesthesia and Pain Therapy (ESRA Hellas) and the Hellenic Aerosol Association (HAA). The inventory team does not have adequate data in order to perform the calculations based on the methodology described in the IPCC guidelines.

4.23 Other Use of Solvents and Related Activities (CRT Source Category 2.G.4)

4.23.1 Description

In this category CO_2 and NMVOC emissions from other uses of solvents are included. Namely emissions calculated are emissions from:

- Wood preservation
- Printing industry
- Glue production
- Production and processing of PVC
- Domestic solvent use (except paint application)
- Production of pharmaceutical products
- Fat edible and non edible oil extraction and
- Ink production

4.23.2 Methodology

The emission factors used for some of the activities defined in EMEP CORINAIR and for which it was possible to obtain the corresponding activity data from the Hellenic Statistical Authority, are for:

1. Printing industry
2. Production and processing of PVC
3. Domestic solvent use (except paint application)
4. Production of pharmaceutical products
5. Ink production
6. Fat edible and non edible oil extraction
7. Wood preservation
8. Glue production

Emissions of NMVOC, associated to total mass of products produced were calculated by applying Tier 1 methodology with EFs from EMEP/EEA air pollutant emission inventory guidebook 2016.

Only emissions from Fat, edible and non-edible oil extraction, Application of glues and adhesives and Preservation of wood are estimated using a Tier 2 methodology with EFs from EMEP/EEA air pollutant emission inventory guidebook 2016. Activity data are acquired from ElStat and FAO for these categories.

The NMVOC emissions from the application of glues and adhesives account for about 80% of the emission from the category. Emissions from the ‘Underseal treatment and conservation of vehicles’ and ‘Vehicles dewaxing’ are considered negligible, as it is indicated in the EMEP/EEA air pollutant emission inventory guidebook 2016.

On the other hand, NMVOC emissions will eventually be oxidised to CO_2 in the atmosphere. These CO_2 inputs are included in the national inventory, as suggested by the 2006 IPCC guidelines. They can be calculated from emissions of NMVOCs by using the calculation principles:

$$Inputs\ CO_2 = Emissions\ NMVOC \bullet C \bullet 44/12$$

Where C is the fraction carbon in NMVOC by mass. The default C= 0.6 has been used in this submission.

In ***Table 4.34*** CO_2 emissions (in kt) from Other Uses of Solvents for the whole time series are summarized.

Table 4.34 ***CO_2 and NMVOC emissions (in kt) from Other Uses of Solvents for the period 1990 – 2023.***

Year	Total CO2 emissions (kt)	Total NMVOC Emissions (kt)
1990	102.47	36.32
1991	105.72	37.88
1992	103.93	36.75
1993	100.86	35.68
1994	96.65	33.77
1995	90.56	31.24
1996	89.04	34.46
1997	89.77	31.21
1998	90.86	31.56
1999	96.42	34.52
2000	93.93	33.97
2001	94.93	33.18
2002	91.49	32.78
2003	95.09	33.57
2004	97.41	34.71
2005	94.77	35.22
2006	95.78	34.19
2007	96.70	34.69
2008	94.20	33.27
2009	90.62	30.71
2010	93.36	33.21
2011	88.13	32.43
2012	85.27	30.40
2013	86.16	31.09
2014	83.33	29.91
2015	83.81	30.44
2016	84.00	29.80

2017	84.72	30.29
2018	87.07	31.26
2019	86.90	30.73
2020	88.05	31.21
2021	88.16	33.09
2022	88.23	33.40
2023	88.48	33.67

4.23.3 Uncertainty and time-series consistency

The uncertainty of the activity data and the EF for the CO_2 emissions estimation is 5%. As reported in the 2006 IPCC Guidelines usually for this source category only small annual changes are expected.

The general trend in all cases presents a decrease in emissions during the last years, due to the economic recession. Especially for printing industry a maximum value was presented in 2004 which could be connected with the organization of the Olympic games in Greece during that year.

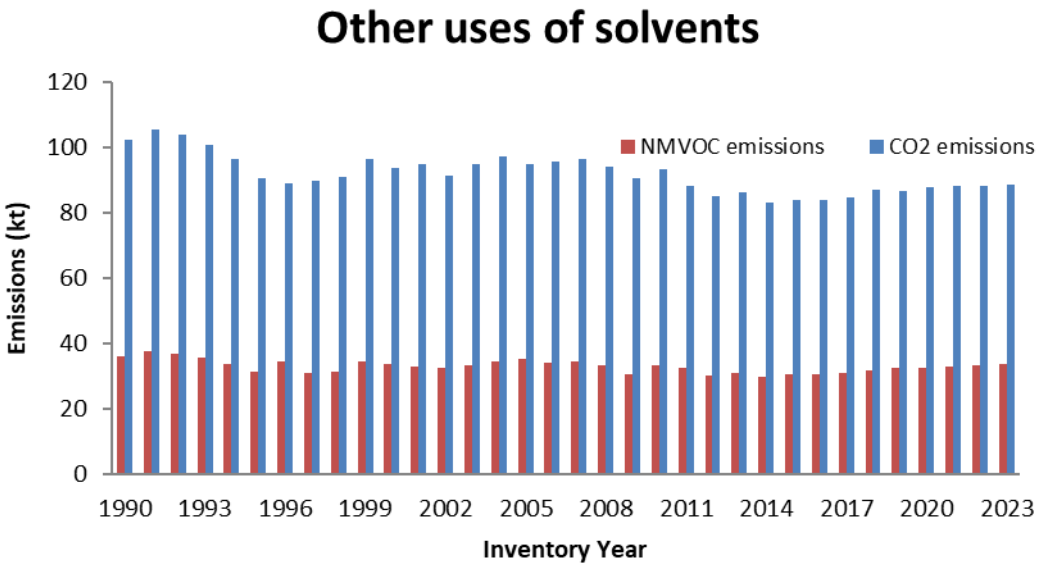


Figure 4.26 CO2 and NMVOC emissions (in kt) from other uses of solvents for the period 1990 – 2023.

4.23.4 Source-specific QA/QC and verification

Activity data derive from:

- The Prodcom database of the Hellenic Statistical Authority (www.statistics.gr) for finishing, others, paints and ink manufacturing.

- EUROSTAT database (http://ec.europa.eu/eurostat/data/database) for Glues and adhesive manufacturing, paints and ink manufacturing.
- FAOSTAT database (http://faostat.fao.org).

In absence of other data availability, the QC tests include the annual update and double check of the population data provided by ElStat and EuroStat. The data provided by Eurostat are available for the whole time series.

4.23.5 Recalculations

No recalculations were performed under this submission.

4.23.6 Planned improvements

There are no improvements planned for this category.

5. Agriculture (CRT sector 3)

In this chapter, GHG emissions estimates from the sector *Agriculture* are presented and the calculation methodologies per source category are described.

According to the IPCC Guidelines, the following source categories are included in this sector:

- Enteric fermentation
- Manure management
- Rice cultivation
- Agricultural soils
- Field burning of agricultural residues

The remainder of this chapter is organised as follows. Paragraph 5.1 continues with the presentation of emissions trends from agriculture, a brief description of the methodology applied for the calculation of GHG emissions and the assessment of the completeness of the GHG inventory for agriculture. Then (Paragraphs 5.2 – 5.8) detailed information on the methodologies applied (including references on the activity data and the emission factors used) for the calculation of GHG emissions per source category is presented.

5.1.1 Emissions trends

GHG emissions from *Agriculture* decreased by 24.4% between 1990 and 2023 (***Figure 5.1***), with an average annual rate of decrease of 0.74. The steep decrease observed for the years 1993 and 1994 is due to the cut backs in public incentives for the use of synthetic fertilizers.

Emissions from *Agriculture* and especially N_2O emissions from agricultural soils are characterized by intense fluctuations during the period 1990 – 2023. The annual variations of agricultural production and the amount of synthetic fertilizers applied are the main causes for these fluctuations. Agricultural production data were derived from the Hellenic Statistical Authority (ELSTAT), while confirmed data for the quantities of synthetic fertilizers applied in soils derive for the first time from the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers (PHAPFPD).

Agriculture is responsible for methane and nitrous oxide emissions. Emissions per gas from agriculture are presented in ***Table 5.1***.

Table 5.1 GHG emissions (in kt CO_2 eq) per gas from Agriculture

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2	60	58	56	44	41	45	46	44	44	42	38
CH_4	5664	5659	5576	5582	5451	5620	5632	5644	5614	5610	5551
N_2O	4811	4831	4640	4165	4032	4222	4260	4178	4165	4082	3974
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CO_2	37	36	35	36	32	30	34	29	25	30	26
CH_4	5575	5619	5656	5625	5612	5623	5622	5525	5490	5602	5562
N_2O	3924	3882	3821	3879	3693	3592	3714	3538	3366	3566	3377
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CO_2	25	26	24	23	26	34	33	35	37	38	31
CH_4	5494	5395	5212	5101	5009	4989	5023	4964	5163	5115	4996
N_2O	3321	3334	3111	3042	3122	3166	3065	3102	3221	3203	2949
Year	**2023**										
CO_2	31										
CH_4	4975										
N_2O	2963										

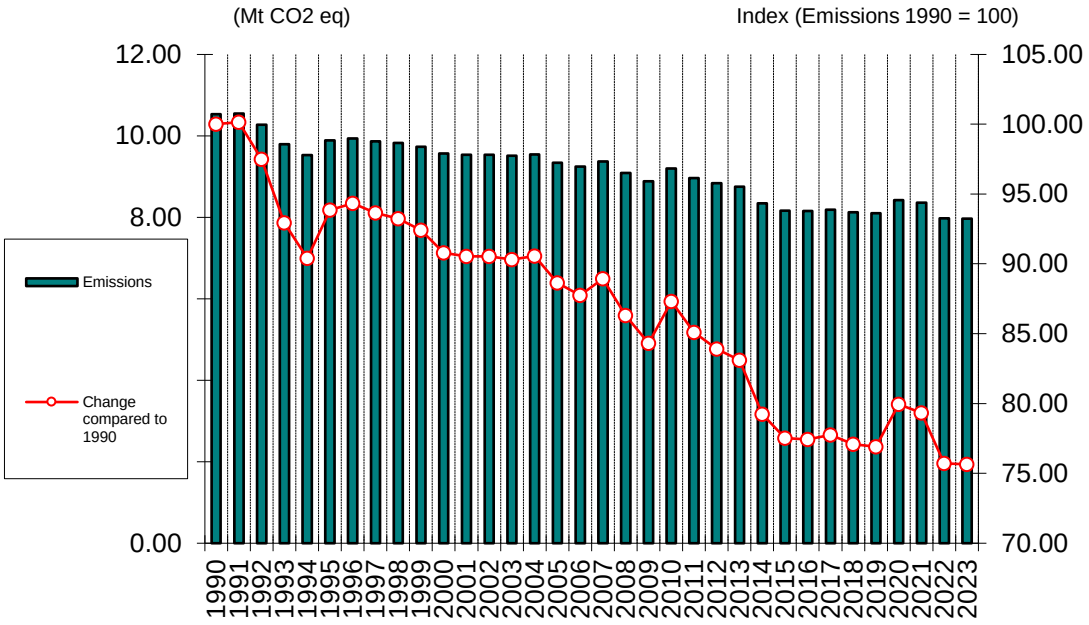


Figure 5.1 Total GHG emissions (in kt CO_2 eq) from Agriculture

Methane represents the main GHG from *Agriculture*, with a contribution ranging from 53.7% to 62.6%. Methane emissions in 2023 decreased by 12.2% compared to 1990 levels with an average annual rate of decrease estimated at 0.37%.

Enteric fermentation is the main source of emissions from *Agriculture* (***Figure 5.2***), accounting for 43.7 % - 51.8% of the total emissions from the sector.

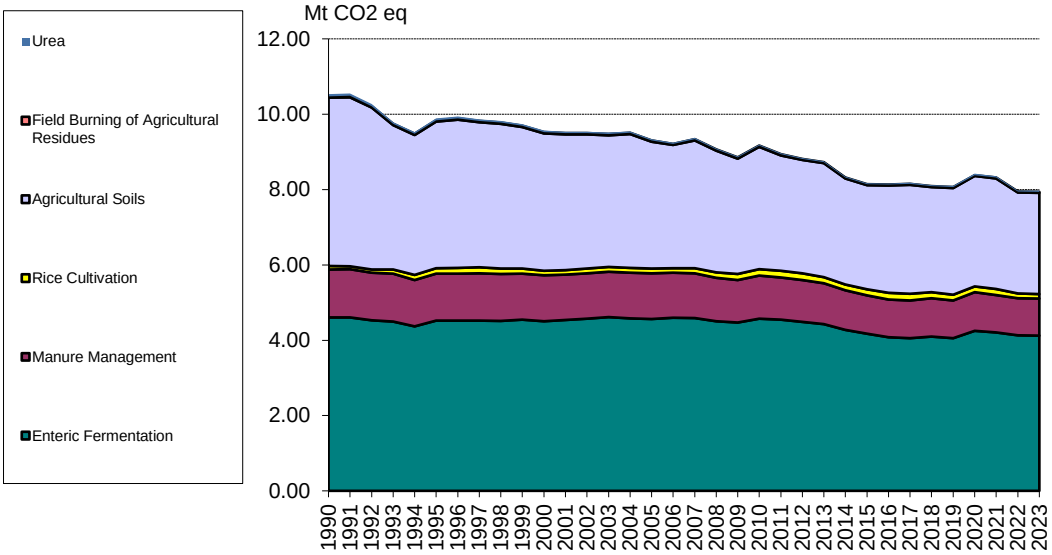


Figure 5.2 GHG emissions (in kt CO_2 eq) from Agriculture per source category

5.1.2 Methodology

The calculation of GHG emissions from *Agriculture* is based on the methodologies and emission factors suggested by the 2006 IPCC Guidelines.

Data on animal population, agricultural production and cultivated areas used for the emissions calculation were provided by the ELSTAT, while data on the amount of synthetic fertilizers applied to soils derive from Pan-Hellenic Association of Professional Fertilizers Producers & Dealers.

The methodology applied for the calculation of emissions per source category is briefly presented in ***Table 5.2***, while a detailed description is given in the corresponding paragraphs (Paragraphs 5.2 – 5.8).

Key categories

Enteric fermentation has been identified as a key category (dairy, non dairy cattle, sheep and other animal). Agricultural soils (indirect emissions and direct emissions) are key categories. (see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations) The key categories from agricultural sector are presented **Table 5.3**.

Table 5.2 Methodologies for the estimation of emissions from Agriculture

	CO_2O		CH_4		N_2O	
	Method	Emission factor	Method	Emission factor	Method	Emission factor
Enteric fermentation – Dairy cattle			T2	CS, D		
Enteric fermentation – Non dairy cattle			T2	CS, D		
Enteric fermentation – Sheep			T2	CS, D		
Enteric fermentation – Other animal			T1	D		
Manure management			T2, T1	CS, D	D	D
Rice cultivation			T1	D		
Agricultural soils					T1	D
Field burning of agricultural residues			T1	D	T1	D
Urea application	D	D				

T1 and T2: IPCC methodology Tier 1 and 2 respectively

D: IPCC default methodology and emission factor, CS: Country specific emission factor

Table 5.3 Key categories from the Agriculture sector

Source category	Gas	Level assessment	Trend assessment
Enteric fermentation	CH_4	☒	☒
Manure Management	CH_4	☒	
Direct emissions from agr soils	N_2O	☒	☒
Iindirect emissions	N_2O	☒	☒

Uncertainty

The results of the uncertainty analysis undertaken for the Greek GHG emissions inventory are presented in Paragraph 1.7, while the detailed calculations are presented in Annex IV.

5.1.3 Completeness

Table 5.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in agriculture.

Table 5.4 Agriculture – Inventory completeness

	CO_2	CH_4	N_2O

A. Enteric fermentation		☒	
B. Manure management		☒	☒
C. Rice cultivation		☒	
D. Agricultural soils			
1. Direct emissions		NE	☒
2. Animal production		NE	☒
3. Indirect emissions		NE	☒
E. Prescribed burning of savannas			
F. Field burning of agricultural residues		☒	☒
G. Liming			
H. Urea application	☒		

NE: Not estimated

Methane emissions from agricultural soils are not estimated since appropriate methodologies have not been developed yet.

5.2 Enteric fermentation (CRF Source Category 3A)

5.2.1 Description

Methane is produced during the normal digestion of food by herbivorous animals and the amount emitted depends on the animal species, their digestive system and feed intake.

Enteric fermentation (CH_4 emissions) of sheep and other animal are key categories. As already mentioned, the Tier 2 methodology is applied for the estimation of methane emissions from enteric fermentation of cattle and sheep, according to the recommendation of the IPCC Guidelines. The Tier 1 methodology and the default emission factors suggested by the IPCC Guidelines are used for the rest of the animal species.

Methane emissions from enteric fermentation in 2023 account for 51.7% of total GHG emissions from *Agriculture*. The average annual rate of decrease of emissions from enteric fermentation for the period 1990 – 2023, is estimated at 0.32% (decrease by 10.5% in 2023 compared to 1990). Emissions from enteric fermentation are presented in ***Table 5.5***.

Table 5.5 CH_4 emissions (kt) from enteric fermentation for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH_4 emissions (kt)	164.39	164.64	161.81	160.62	156.13	161.42	161.54	161.65	161.28	162.34	160.80
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CH_4 emissions (kt)	162.06	163.41	164.75	163.59	163.03	164.36	163.85	161.06	159.67	163.36	162.34
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CH_4 emissions (kt)	160.45	158.24	152.81	149.08	145.62	144.91	146.45	144.87	151.72	150.20	147.6
Year	**2023**										
CH_4 emissions (kt)	147.14										

5.2.2 Methodology

Enteric fermentation of dairy cattle

Methane emissions from the enteric fermentation of dairy cattle are estimated according to the Tier 2 IPCC methodology, as it is described in the 2006 IPCC Guidelines.

The calculation of the emission factors for each activity is based on the following equation:

$$EF_i = \frac{GE_i \cdot Ym_i \cdot 365}{55.65}$$

where *I* is the activity, EF_i is the estimated emission factor for CH_4 (kg CH4/head/yr), GE_i is the gross energy intake (MJ/head/day) and *Ym* is the methane conversion rate which is the fraction of the gross energy in feed converted to CH_4.

The calculation of gross energy for sheep is based on the following equation:

$$GE = \left[\left(NE_m + NE_a + NE_l + NE_p \right) \Big/ \left(NE_{ma} / DE \right) + \left(NE_g \right) \Big/ \left(NE_{ga} / DE \right) \right] / \left[DE \big/ 100 \right]$$

where:

NE_m is the net energy required for animal maintenance, MJ/day

NE_a is the net energy for animal activity, MJ/day

NE_l is the net energy for lactation, MJ/day

NE_p is the net energy required for pregnancy, MJ/day

NE_g is the net energy for growth, MJ/day

DE is the digestible energy expressed as a percentage of gross energy

NEma/DE is the ratio of net energy available in a diet for maintenance to digestible energy consumed

NEga/DE is the similar ratio for growth.

The number of dairy cattle used for the calculation of methane emissions, obtained by EL.STAT (on the basis of a statistical analysis of data available on the last day of the year, obtained from a survey performed annually in autumn) is presented in ***Table 5.6***. Average milk production (for 365 days) is provided by the EL.STAT., the only available official milk production data, while milk production yield during suckling estimated at 0.6 kg/day (estimated for 365 days).

For the estimation of average bodyweight of dairy cattle and the digestibility of feed, a linear approach based on milk yield has been utilized following 2021 TERT (EU review team) recommendation in the framework of 2021 review.

As per said approach, figures from "2006 IPCC Guidelines, Vol. 4, Ch. 10, Table 10A.1", for Dairy Cattle in Western Europe and in Eastern Europe have been utilized, i.e.:

i. For milk yield 16.4 kg/day, DE: 70% and Weight 600 (Western Europe)

ii. For milk yield 7.0 kg/day, DE: 60% and Weight 550 (Eastern Europe)

thus, the following linear equations are utilized:

DE(%)=1.064*Milk(kg/d)+52.55, and

Weight(kg)=5.32*Milk(kg/d)+513.

For the estimation of net energy for dairy cattle activity, it was considered that they are confined to a small area thus no energy is required to acquire feed (C_a = 0), for the 92% of the time life of dairy cattle. For the rest period, i.e. the 8%, in which dairy cattle are on paddock or pasture, Ca equal to 0.17 is considered.

Default values for *Ym* (0.65) from IPCC Guidelines were utilized.

Table 5.6 Number of dairy cattle in 1000s for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Dairy cattle (1000s)	210	214	203	219	168	192	184	184	172	154	180
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Dairy cattle (1000s)	172	152	149	157	153	149	158	137	128	144	130
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dairy cattle (1000s)	132	130	135	111	106	97	95	86	90	91	80
Year	2023										
Dairy cattle (1000s)	80										

Finally, in ***Table 5.7*** information regarding gross energy (GE) and emission factor are presented.

Table 5.7 Gross energy (GE) for dairy cattle for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
GE (MJ/head/day)	255	255	260	259	270	266	268	267	271	276	269
EF, (kg CH_4/head/yr)	108.9	108.7	110.8	110.6	115.3	113.3	114.1	114.0	115.5	117.5	114.7
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
GE (MJ/head/day)	272	279	278	278	282	283	278	286	289	286	290
EF, (kg CH_4/head/yr)	115.8	119.0	118.3	118.4	120.2	120.5	118.7	121.9	123.4	121.7	123.6
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
GE (MJ/head/day)	289	290	284	292	292	292	296	300	296	295	303
EF, (kg CH_4/head/yr)	123.2	123.7	121.1	124.6	124.4	124.4	126.0	128.0	126.3	125.9	129.3
Year	2023										
GE (MJ/head/day)	303										
EF, (kg CH_4/head/yr)	129.3										

Enteric fermentation of other cattle

Similar with the dairy cattle, methane emissions from the enteric fermentation of other cattle are estimated according to the Tier 2 IPCC methodology, as it is described in the 2006 IPCC Guidelines.

The characterization and classification of other cattle was based on data from ELSTAT (on the basis of a statistical analysis of data available on the last day of the year, obtained from a survey performed annually in autumn) and the statistics department of the Ministry of Agriculture, as well as on estimates by experts in agricultural issues. The population of other cattle for each sub-category is presented in ***Table 5.8***.

The calculation of the emission factors for each activity is based on the equation presented above for the dairy cattle. In ***Table 5.9*** parameters used for the estimation of emissions from other cattle is presented as well as the gross energy (GE) and the emissions factors (EFs) for the 2023. Portion of female cattle, >2 year old, giving birth is estimated at 0.9 while milk production yield estimated at 0.08 kg/day (estimated for 365 days), based on official data provided by EL.STAT. and milk production yield during suckling estimated at 1.0 kg/day (estimated for 365 days). Milk fat content is estimated at 4% while for the estimation of net energy for other cattle activity, it was considered that they are confined in areas with sufficient forage requiring modest energy expense to acquire

feed. (C_a = 0.17). Default values for *Ym* (0.65) from IPCC Guidelines were utilized. DE value for non-dairy 65% based on IPCC 2006 (Table 10.2 and Table 10.A.1) and other EU parties taking into consideration that a high share of their life are Pasture fed.

Relevant to the weight gain for other cattle, based on the animal sex-age groups provided by the ELSTAT and the relevant weight per group, the information by the IPCC 2006 (TABLE 10A.2) and the analysis provided by other Mediterranean parties, e.g. Portugal and Italy has been utilized providing the following figures:

1. Age <1 year, For slaughter as calves: 0.6 kg/day
2. Age <1 year, Females: 0.6 kg/day
3. Age <1 year, Males: 0.7 kg/day
4. 1-2 years, Females: 0.2 kg/day
5. 1-2 years, Males: 0.3 kg/day

For mature sheep 0 kg/day is considered.

Enteric fermentation of sheep

Methane emissions from the enteric fermentation of sheep are estimated according to the Tier 2 IPCC methodology, as it is described in the 2006 IPCC Guidelines. For the calculation of the net energy required for each animal sub-category and activity, the appropriate in each case factors suggested in the 2006 IPCC Guidelines were used. The calculation of the emission factors for each animal sub-category and activity is based on the following equation:

$$EF_i = \frac{GE_i \cdot Ym_i \cdot 365}{55.65}$$

where *I* is the activity, EF_i is the estimated emission factor for CH_4 (kg CH4/head/yr), GE_i is the gross energy intake (MJ/head/day) and *Ym* is the methane conversion rate which is the fraction of the gross energy in feed converted to CH_4.

Table 5.8 Number of other cattle (in 1000s) for each sub-category

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
< 1 year											
For slaughter as calves	110	91	103	85	53	61	60	58	38	64	50
Females	67	62	55	52	55	65	51	57	56	44	57
Males	45	41	39	37	57	63	57	57	62	47	57
1-2 years											
Females	55	54	50	52	39	44	45	47	41	49	41
Male	65	66	60	51	46	53	59	57	54	67	50
> 2 year											
Females	136	151	130	107	116	118	129	130	146	161	119
Males	8	6	8	5	5	7	8	6	10	16	12
Total	**487**	**471**	**446**	**390**	**371**	**411**	**409**	**413**	**407**	**447**	**386**

Sub-categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
< 1 year											
For slaughter as calves	45	63	65	68	72	72	65	64	94	71	66
Females	50	60	62	61	56	61	63	54	41	55	69
Males	49	62	67	61	67	62	71	51	33	56	56
1-2 years											
Females	45	55	56	58	53	59	57	56	63	70	73
Males	38	48	61	71	79	73	65	64	65	66	52
> 2 year											
Females	145	161	177	174	171	195	173	193	177	200	213
Males	13	13	14	12	13	14	17	15	21	17	21
Total	**386**	**462**	**501**	**506**	**510**	**535**	**512**	**497**	**494**	**535**	**551**

Sub-categories	2012	2013	2014	2015	2016	2017	2018	2019
< 1 year								
For slaughter as calves	75	48	63	54	38	40	35	46
Females	70	70	67	57	59	61	61	63
Males	58	51	46	43	48	50	45	48
1-2 years								
Females	76	68	70	57	59	58	58	53
Males	55	76	49	46	43	43	37	38
> 2 year								
Females	198	207	210	198	181	189	194	183
Males	21	21	19	16	19	17	16	14
Total	**553**	**542**	**524**	**471**	**448**	**458**	**446**	**444**

Sub-categories	2020	2021	2022	2023
< 1 year				
For slaughter as calves	43	47	41	41
Females	68	74	66	67
Males	51	55	49	49
1-2 years				
Females	84	66	62	62
Male	60	47	44	45
> 2 year				
Females	203	207	213	214
Males	27	20	19	19
Total	**536**	**517**	**494**	**497**

Table 5.9 ***Mean Weight, Gross energy (Gei), CH_4 conversion rate (Ym) value and emissions factor (Efs) for each subcategory of other cattle for 2023***

	Mean Weight (kg)	Gross Energy (Gei) MJ/day/head	Conversion rate (Ym)	Emissions factors (EF) $KgCH_4$/head/yr
< 1 year				
For slaughter as calves	200	92.2	0.065	39.3
Females	180	95.8	0.065	40.8
Males	230	107.2	0.065	45.7
1-2 years				
Females	450	145.8	0.065	62.1
Males	500	158.7	0.065	67.7
> 2 year				
Females	550	177.5	0.065	75.7
Males	750	209.9	0.065	89.5
Average	**418**	**145.2**	**0.065**	**63.12**

The calculation of gross energy for sheep is based on the following equation:

$$GE = \left[\left(NE_m + NE_a + NE_l + NE_p\right) \Big/ \left(NE_{ma} / DE\right) + \left(NE_g + NE_{wool}\right) \Big/ \left(NE_{ga} / DE\right) \right] \Big/ \left[DE \big/ 100 \right]$$

where:

NE_m is the net energy required for animal maintenance, MJ/day

NE_a is the net energy for animal activity, MJ/day

NE_l is the net energy for lactation, MJ/day

NE_p is the net energy required for pregnancy, MJ/day

NE_g is the net energy for growth, MJ/day

NE_{wool} is the net energy for growth, MJ/day

DE is the digestible energy expressed as a percentage of gross energy

NEma/DE is the ratio of net energy available in a diet for maintenance to digestible energy consumed

NEga/DE is the similar ratio for growth.

The characterization and classification of sheep was based on data from ELSTAT (on the basis of a statistical analysis of data available on the last day of the year, obtained from a survey performed annually in autumn) and the statistics department of the Ministry of Agriculture, as well as on estimates by experts in agricultural issues. The estimation of sheep population for each sub-category is presented in ***Table 5.10***.

Table 5.10 Number of sheep (in 1000s) for each sub-category

Sub-categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Milking ewes											
Milk production	5235	5254	5239	5263	5321	5361	5378	5370	5398	5411	5435
Only suckling	394	395	394	396	400	404	405	404	406	407	409
Other female sheep > 1 year	732	734	732	736	744	749	752	751	755	756	760
Males > 1 year old	394	395	394	396	400	404	405	404	406	407	409
Female lambs	1524	1530	1525	1532	1549	1561	1566	1564	1572	1575	1582
Male lambs	381	382	381	383	387	390	391	391	393	394	396
Born sheep	8352	8482	8627	8660	8704	8820	8837	8866	8863	8918	8949
Total	**8660**	**8692**	**8666**	**8706**	**8802**	**8869**	**8896**	**8884**	**8930**	**8951**	**8991**
Sub-categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Milking ewes											
Milk production	5517	5476	5442	5336	5315	5338	5378	5373	5399	5382	5388
Only suckling	415	412	410	402	400	402	405	404	406	405	406
Other female sheep > 1 year old	771	765	761	746	743	746	752	751	755	752	753
Males > 1 year old	415	412	410	402	400	402	405	404	406	405	406
Female lambs	1606	1594	1584	1554	1547	1554	1566	1564	1572	1567	1569
Male lambs	402	399	396	388	387	389	391	391	393	392	392
Born sheep	9033	9034	9049	9029	8994	9001	8998	9008	9052	9100	9016
Born sheep Total	**9127**	**9058**	**9002**	**8827**	**8792**	**8830**	**8897**	**8889**	**8931**	**8904**	**8914**
Sub-categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Milking ewes											
Milk production	5307	5205	5127	5287	5247	5250	5385	5391	5399	5472	5451
Only suckling	399	392	386	398	395	395	405	406	406	412	410
Other female sheep > 1 year old	742	728	717	739	733	734	753	754	755	765	762
Males > 1 year old	399	392	386	398	395	395	405	406	406	412	410
Female lambs	1545	1516	1493	1539	1528	1529	1568	1570	1572	1593	1587
Male lambs	386	379	373	385	382	382	392	392	393	398	397
Born sheep	**8844**	**8835**	**8827**	**7993**	**7681**	**7685**	**8093**	**8324**	**8365**	**8196**	**8204**
Total	**8778**	**8611**	**8481**	**8746**	**8680**	**8685**	**8909**	**8918**	**8931**	**9052**	**9017**
Sub-categories	2023										
Milking ewes											
Milk production	5429										
Only suckling	409										
Other female sheep > 1 year old	759										
Males > 1 year old	409										
Female lambs	1581										

Male lambs	395
Born sheep	8289
Total	**8981**

The fact that the population for "Milking ewes-Only suckling" and "Males > 1 year old" are identical does not imply any special connection between them, and it is only the result of the assuptions followed for the calculation of sub-categories population. Moreover, to clarify the figures above, only 25% of lambs live past the lactation period and 4 female lambs for each male lamb are kept for reproduction in the mature phase of their lives.

The average bodyweight of sheep at weaning is estimated at 15 kg while the average weights of female and male mature sheeps (>1 year) are estimated at 53 kg and 70 kg respectively.

The average milk production for domestic and in flock and for nomadic sheep was re-estimated equal to 0.30 kg/day and 0.27 kg/day respectively estimated for 365 days for 2012, utilizing the only available official milk production data provided by the EL.STAT (Recommendations by the 2013 ERT).

The milk production of mothers during suckling estimated at 0.12 kg/day (for 365 days). Wool production is estimated for all the mature sheep at 4 kg/sheep/year.

Due to lack of data concerning the births of lambs the following assumption was adopted. It was considered that all milked mature sheep give birth. Some of the milked sheep give single birth while the other one give a double such the total number of lambs to be equal with these obtained by the ELSTAT as born.

Relevant to the weight gain for young sheep, following IPCC 2006 guidelines, i.e.:

WGlamb = the weight gain (BWf – BWi), kg yr-1

BWi = the live bodyweight at weaning kg

BWf = the live bodyweight at 1-year old or at slaughter (live-weight) if slaughtered prior to 1 year of age, kg

The following data have been developed:

1. Females: 0.12 kg/day

2. Males: 0.17 kg/day

Default methane conversion rates (*Ym*) which correspond to high digestibility were selected from the 2006 IPCC Guidelines. In ***Table 5.11*** information regarding gross energy (Gei), CH_4

conversion rate (Ym) values and emissions factors (Efs) for each subcategory of sheep (such as grazing, lactation and growth) is presented for 2022.

The duration of lamb's growth is estimated at 315 days, which correspond to the period between effective weaning and one year of age, suckling lasts 50 days, while pregnancy lasts 147 days.

Table 5.11 Gross energy (Gei), CH_4 conversion rate (Ym) value and emissions factor (Efs) for each subcategory of sheep for 2023

	Gross Energy (Gei) MJ/day/head	Conversion rate (Ym)	Emissions factors (EF) $KgCH_4$/head/yr
Female lamb	17.3	0.045	5.1
Female sheep – milking ewes	25.4	0.065	10.8
Female sheep – other	20.2	0.065	8.6
Male lamb	22.1	0.045	6.5
Male sheep	26.2	0.065	11.2
Average	**23.4**	**0.062**	**9.5**

Methodology for enteric fermentation for the other animals

Methane emissions from enteric fermentation for the other animals are estimated according to the Tier 1 IPCC methodology. Methane emissions from enteric fermentation for poultry are estimated based on proposed by Switzerland emission factor to improve the inventory completeness as it was strongly requested by the previous ERTs, and given the fact that no figure is proposed by the IPCC guidelines. ***Table 5.12*** shows utilized emission factors.

To be noted that since enteric fermentation is a key category, for the estimation of emissions from goats (comprising the high majority of emissions from "other animals" compared to other species), a Tier 2 approach should be used. However, this cannot be carried out, since as clarified in 2006 IPCC GLs, a Tier 2 method is available only for sheep and cattle, but not for goats.

More specifically:

(a) on page 10.15 of the 2006 IPCC GLs, there is one equation (10.3) to estimate the net energy for maintenance. This equation is a part of the IPCC Tier 2 method, however, it covers only cattle and sheep, without covering goats (see Tabele 10.4).

(b) on page 10.16 of the 2006 IPCC GLs, there are two equations (10.4 and 10.5) to estimate the net energy for activity. These equations are a part of the IPCC Tier 2 method, however, they cover only cattle and sheep, without covering goats (see Tabele 10.5).

(c) on page 10.17 of the 2006 IPCC GLs, there are two equations (10.6 and 10.7) to estimate the net energy for growth. These equations are a part of the IPCC Tier 2 method, however, they cover only cattle and sheep, without covering goats (see Tabele 10.6).

(d) on page 10.19 of the 2006 IPCC GLs. There is one equation (10.13) to estimate the net energy for pregnancy. This equation is a part of the IPCC Tier 2 method, however, it covers only cattle and sheep, without covering goats (see Tabele 10.7).

Since there is no Tier 2 for goats in the 2006 IPCC GLs, it is considered that the reporting of relevant emissions according to a Tier 1 method is adequate.

The application of this methodology requires livestock population data. Population data were obtained from the ELSTAT, which are provided on the basis of a statistical analysis of data on livestock population available on the last day of the year and the data are from a survey performed annually in autumn.

Table 5.12 Utilized emission factors for enteric fermentation (Table 10.10 IPCC 2006, Developed countries).

	EF kg CH4/head/yr
Buffalo	55.0
Swine	1.5
Horses	18
Mules and Ashes	10
Goats	5
Poultry	0.02

The number of animals used for the calculation of methane emissions is shown in ***Table 5.13***.

As it is obtained by this table, the number of buffalos in Greece follows an increasing trend. This could be justified from the fact that the last years agricultural products from buffalo are becoming year by year more attractive in Greece, resulting in a significant increase in 2015.

Regarding the number of horses, mules and ashes in Greece follows a decreasing trend during the last years, i.e. 2013-2022, since the utilization of horses in agricultural activities is reducing year by year for two different reasons:

a. Economic recession resulting in a reduction of agricultural activities in total.

b. Replacing of horses by agricultural machinery in the execution of agricultural activities.

5.2.3 Uncertainties and time-series consistency

The combined uncertainty of CH_4 emissions of enteric fermentation sector is estimated by 50.2%. The uncertainty associated with activity data is 5% according to uncertainty given by EL.STAT for

the livestock population data. On the other hand, the uncertainty associated with emission factors is 50% as it is estimated according to 2006 IPCC Guidelines. The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the 2006 IPCC Guidelines.

Table 5.13 Number of animals (in 1000s) by category

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Buffalo	0.769	0.939	0.888	0.902	0.692	0.7	0.735	0.788	0.865	0.877	0.975
Swine	996	986	1001	1014	1009	994	987	998	999	973	964
Horses	45	42	40	38	36	35	33	32	31	30	29
Mules and Ashes	187	173	161	150	140	130	121	115	107	101	96
Goats	5334	5336	5365	5378	5444	5525	5570	5600	5615	5614	5639
Poultry	28282	28843	28818	29256	29379	29059	29157	29583	29704	30727	31010
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Buffalo	1.009	1.024	1.11	1.29	1.237	1.389	1.643	1.764	1.785	1.847	2.137
Swine	934	940	937	940	949	902	892	880	862	840	820
Horses	29	28	28	27	27	27	28	28	29	30	32
Mules and Ashes	89	84	79	73	69	64	60	56	52	50	44
Goats	5667	5669	5621	5509	5422	5402	5346	5275	5180	5123	5010
Poultry	28714	30088	29134	30587	31566	31599	31949	29141	28022	29209	28262
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Buffalo	2.167	2.339	4.630	3.812	4.533	4.624	4.489	5.187	5.29	6.14	4.65
Swine	793	761	724	714	698	694	720	706	699	665	678
Horses	31	31	24	21	14	9	6	6	5	5	4
Mules and Ashes	47	41	19	16	8	4	3	3	3	3	2
Goats	4895	4782	4234	4127	3976	3956	3942	3945	3951	3752	3687
Poultry	30804	31078	32362	32111	35857	35823	37605	39497	41459	37193	39224
Year	**2023**										
Buffalo	5.57										
Swine	667										
Horses	4										
Mules and Ashes	2										

Goats	3631
Poultry	41633

5.2.4 Source-specific QA/QC and verification

Quality control and source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures followed in the enteric fermentation source are:

1. Cross checking information provided by the National Statistical Service of Greece and by the Ministry of Rural Development regarding the animal population and the agricultural crop production.
2. Animal population is also checked by comparison with two different works provided by the ELSTAT. The first one is annual statistical survey while the second one is a census of livestock population. The results of the first one were used for the estimation of emissions for cattle while the results of the other for the rest of animals.
3. Comparison of information regarding animal population, agricultural crop production and emissions factors with this of other neighbour countries.
4. Estimations were checked with several calculation tools such as emissions trends and sum deviations.

5.2.5 Recalculations

CH_4 emissions from enteric fermentation have been included for the 2022 due to updated activity data.

The deviation of CH_4 emissions estimated in the current submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 5.14***.

Table 5.14 Recalculations of CH_4 emissions from enteric fermentation

Year	2022
Difference, in kt CO2 eq	12
Impact on total emissions (excl LULUCF), %	0.02

5.2.6 Planned improvements

No modification is planned.

5.3 Manure management (CRF Source Category 3B)

5.3.1 Description

Manure management is responsible for methane and nitrous oxide emissions. Methane is produced during the anaerobic decomposition of manure, while nitrous oxide is produced during the storage and treatment of manure before its use as fertilizer.

CH_4 and N_2O from manure management in 2023 accounted for 9.1% and 3.4% of total GHG emissions from *Agriculture* respectively. CH_4 emissions in 2023 decreased by 23.2% compared to 1990 levels, with an average annual rate of decrease estimated at 0.70% for the period 1990 – 2023. N_2O emissions in 2023 decreased by 20.0% compared to 1990 levels, with an average annual rate of decrease estimated at 0.6%. CH_4 and N_2O emissions from manure management for the period 1990 – 2023 are presented in ***Table 5.15***.

Table 5.15 CH_4 and N_2O emissions (in kt) from manure management, for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH_4 (kt)	33.53	33.44	33.36	33.68	32.80	33.12	32.92	33.12	32.99	32.43	32.50
N_2O (kt)	1.26	1.27	1.24	1.24	1.16	1.21	1.21	1.21	1.21	1.20	1.20
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CH_4 (kt)	31.88	31.81	31.78	31.79	31.83	31.07	31.03	30.33	29.81	29.84	29.28
N_2O (kt)	1.18	1.19	1.19	1.21	1.21	1.20	1.20	1.15	1.12	1.16	1.14
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CH_4 (kt)	28.74	27.97	27.13	26.58	26.16	25.99	26.62	26.24	26.63	25.94	25.91
N_2O (kt)	1.15	1.14	1.10	1.03	1.03	1.01	1.02	1.00	1.06	1.01	0.99
Year	**2023**										
CH_4 (kt)	28.76										
N_2O (kt)	1.01										

5.3.2 Methodology

Manure management systems per animal species

The shares of manure management systems per animal species are presented in ***Table 5.16*** considering 100% conditions of temperate climate region for Greece. Country-specific data for all the animal categories have been considered.

Table 5.16 Manure management systems

Manure management systems	Anaerobic lagoon	Liquid systems	Daily spread	Solid storage and dry lot	Pasture/ range/ paddock	Other system
Dairy cows	0%	5.5%	0%	86.5%	8%	0%
Other cattle	0%	0%	3%	64%	33%	0%
Buffalo	0%	0%	3%	64%	33%	0%
Poultry	0%	0%	0%	100%	0%	0%
Sheep	0%	0%	0%	10%	90%	0%
Swine	0%	90%	0%	10%	0%	0%
Horses	0%	0%	0%	0%	100%	0%
Mules and ashes	0%	0%	0%	0%	100%	0%
Goats	0%	0%	0%	10%	90%	0%
Rabbits	0%	0%	0%	100%	0%	0%

Dairy Cattle

For the estimation of the dairy cattle manure management systems' allocation, information received by several agricultural experts was utilized:

- the Ministry of Rural Development and Food,
- the Greek Regions with high population of animals (Ipiros, Thessalia etc.),
- the Hellenic statistical Authority (EL.STAT.) and
- the Technological Educational Institute of Thessaloniki.

According to this information:

- In old farms and in farms with small population of animals (<30), only solid management practice is performed using manure piles.
- In new units with high population of dairy cattle (>30) manure is either stored in piles or separation of liquid-solid is performed. Solid is stored to piles, while liquid is stored to tanks.
- Where liquid-solid separation of manure is performed, in about 40% of the total dairy cattle farms, 15% of solid is drifted by the liquid, and thus, this solid part of manure is treated under liquid conditions.
- **8% of the total produced manure from the dairy cattle remains in pasture / range / paddock.**

Therefore, the produced manure that is managed in liquid systems is:

$$f_{solid} = 40\% * 15\ \% = 6\ \%$$

Given that 8 % of the animal remains in pasture / range / paddock the real solid treated in liquid systems is:

Solid manure treated in liquid systems = 6 %* 92% of total solid produced manure or

Solid manure treated in liquid systems = 5.52 % of total solid produced manure

While the rest (94% * 92% = **86.48%** of total solid produced manure) is treated by solid manure management systems (i.e. manure piles).

However, it must be noticed that for the estimation of N_2O emissions the assumption by the IPCC GPG p4.44 that 50% of the nitrogen excreted is in the faeces and 50% is in the urine was utilized, according to.

Since 40 % of the produced manure is separated to liquid and solid, while 15% of solid manure drifts with the liquid, the liquid product of the separation contains 50% of nitrogen excreted, which is in the liquid phase, as well as 7.5% (=15%*50%), which is 15% of the remaining 50% of nitrogen contained in solid. Thus, the fraction (f_N) of nitrogen excretion treated in liquid manure management systems is estimated as follows:

$$f_N=50\%+50\%*15\%=57.5\%$$

The produced nitrogen excretion that is treated in liquid systems is:

N excretion treated in liquid systems = 40% * 57.5 % *92%*total produced manure or

N excretion treated in liquid systems = 21.16%*total N excretion produced

While the rest of nitrogen excreted is treated by solid manure management systems (i.e. manure piles). Therefore, for the estimation of N_2O emissions the allocation of the manure management systems is modified to 21% liquid systems, 71 % solid systems and 8 % Pasture/ range/ paddock

Other Cattle and Buffalo

The allocation of manure to animal waste management systems of other cattle and buffalo results as follows. Almost the 60% of them, the animal in age of 1 year and older, remain in pasture for about seven months per year while the young animal remain mainly in stall. For the rest of the time, all the other cattle are in stall. Thus, it is estimated that about 33% of the produced manure by other cattle fall in pasture while the rest is mainly managed in Solid storage and dry lot systems.

Swine

The majority of swine in Greece remain in properly designed building infrastructures and their manure is managed with liquid systems according to Greek legislation. A small share of swine's manure, about 10%, is managed with solid systems. This share mainly represents the manure produced by swine live in small production units.

Sheep, goats, poultry

The allocation of manure to animal waste management systems of other animal, like sheep, goats and poultry were reconsidered utilizing information received by several agricultural experts in order to meet the recommendations by the 2012 and 2013 ERTs. The contacted experts are from:

- the Ministry of Rural Development and Food,
- the Greek Regions with high population of animals (Ipiros, Thessalia etc.),
- the Hellenic statistical Authority (EL.STAT.) and
- the Technological Educational Institute of Thessaloniki.

According to this information, almost all the poultry manure is treated with solid practices, while for sheep and goats, only for the 10% of their lives they remain in stables while the other time are in pasture. However, the collection of their manure from the stables is performed only two times per year.

Horses and Mules and ashes

It is estimated that all manure of Horses and Mules and ashes remains in pasture / range / paddock.

Rabbits

Almost all the manure from Rabbits, similarly with poultry, is considered to be treated with solid practices.

CH_4 emissions from manure management

CH_4 emissions from manure management were estimated using IPCC Tier 2 approach for dairy cattle and other cattle and sheep. Parameters used to estimate country-specific EFs for these categories are presented in **Table 5.17**.

For the rest of the animals T1 methodology is used. Utilized emissions factors for 2023 are shown in ***Table 5.17***.

Table 5.17 Parameters used to estimate ountry-specific EFs for Dairy cattle, other cattle and sheep.

	Dairy cattle	Other cattle	Sheep
DE, %	74.0	65	65
ASH, %	8	8	8
VS, kg/day	4.5	2.8	0.46
Bo, m^3/kg of VS	0.24	0.17	0.19
MCF	Liq. /Sol. 22 / 4	D.Spred./Sol./Past. 0.5 / 4 / 1.5	Sol./Past. 35 / 1.5

MCF figures come from Table 10.17, IPCC 2006 for temperature 18ºC for Solid storage, Liquid, Daily spread and Pasture for all animal. For sheep, the figure 35 corresponds to Pit storage below animal confinements for the same temperature.

Table 5.18 Utilized emission factors for manure management emissions for 2023.

	EF kg CH4/head/yr	Source
Dairy cattle	12.72	T2
Non-dairy cattle	3.60	T2
Sheep	1.03	T2
Buffalo	9.0	TABLE 10.14, IPCC 2006, Eastern. Europe at 18°C*
Swine	17.35	T2, See explanation below**
Horses	2.34	TABLE 10.15, IPCC 2006, Temperate (15 to 25°C), Developed countries
Mules and Ashes	1.1	TABLE 10.15, IPCC 2006, Temperate (15 to 25°C), Developed countries
Goats	0.2	TABLE 10.15, IPCC 2006, Temperate (15 to 25°C), Developed countries
Laying hens	0.03	TABLE 10.15, IPCC 2006, Temperate (15 to 25°C), Developed countries
Other Poultry	0.09	TABLE 10.15, IPCC 2006, Temperate (15 to 25°C), Developed countries
Rabbits	0.08	TABLE 10.15, IPCC 2019

*The default EF for Eastern Europe for buffalo (9 kg CH4/head/year, at an average annual temperature of 18 °C) is considered because the solids-based systems predominantly used for the management of buffalo manure in Greece are more similar to those used in Eastern Europe rather the liquid/slurry and pit storage systems commonly used for the management of cattle manure in Western Europe.

**Relevant to Swine, it should be noted that the high majority of big swine breeding units is located on level communes, thus, the mean annual temperature is close to 23◦C. Considering that market swine consist of the 90% of total swine population and the breeding swine the 10%, Tier 2 approach is used utilizing parameters from Tables 10A-7 and 10A-8 of IPCC 2006 GLs:

For Western Europe conditions:

Market Swine: Vs=0.3, Bo=0.45, MCF for liquid = 0.55, MCF for solid = 0.04 for temperature 23ºC

Breeding Swine: Vs=0.46, Bo=0.45, MCF for liquid = 0.55, MCF for solid = 0.04 for temperature 23 ºC.

Based on these parameters, the estimated IEF is approximately 17.35 kg CH_4 per head per year

N_2O emissions from manure management

In order to calculate N_2O emissions from manure management, the default IPCC methodology was used, according to the following equation.

$$E = \sum_S \left(\sum_T \left(N_T \cdot Nex_T \cdot MS_{(T,S)} \right) \right) \cdot EF_S$$

where E is N_2O emissions, T is the animal species index, S is the manure management system index, $N_{(T)}$ is the livestock population, $Nex_{(T)}$ the annual average N excretion per head of species, $MS_{(T,S)}$ the fraction of total annual excretion for each livestock species that is managed in system S, $EF_{(S)}$ is the N_2O emission factor for system S.

For the estimations of annual nitrogen excretion rate for dairy cattle, the proposed methodology Tier 2 IPCC 2006 Guidelines (EQUATION 10.31 and EQUATION 10.32) is utilized considering crude protein in diet percent (CP) by 16.5%, following recommendations of 2016 TERT (EU review team) in the framework of 2016 comprehensive review of national greenhouse gas inventory data pursuant to Article 19(1) of Regulation (EU) No 525/2013.

For the other livestock category, annual nitrogen excretion rates were estimated following the Tier 1 approach proposed by 2006 IPCC Guidelines, Equation 10.30. Country specific data were used

for the TAM, typical animal mass for livestock category, of other cattle and sheep while for the rest animal categories data were collected by Tables 10A-4 to 10A-9 in Annex 10A.2 utilizing data provided for Europe. Default N excretion rate and $N_{rate(T)}$ were collected data by IPCC 2006, Table 10.19 for Eastern Europe apart from dairy cattle were data for Western Europe were utilized. In ***Table 5.19***, total N excretion, TAM and N excretion rate are provided.

Table 5.19 ***Total N excretion (Table 10.19, IPCC 2006, Eastern Europe), TAM and N excretion rate***

	Nrate	TAM (kg)	Nex
Dairy cattle	0.48	620	116.2
Non-dairy cattle	0.35	430	55.0
Buffalo	0.32	380.0	44.4
Sheep	0.9	45.4	14.9
Swine	0.74	50.0	13.5
Horses	0.3	377.0	41.3
Mules and Ashes	0.3	130.0	14.2
Goats	1.28	38.5	18.0
Poultry	0.82	1.8	0.5

Default emission factors for direct N_2O emissions from manure management were utilized (Table 10.21), i.e 0.005 kg N_2O-N/(kg Nitrogen excreted) for liquid and solid systems and 0.001 kg N_2O-N/(kg Nitrogen excreted) for poultry.

Indirect Emissions from Atmospheric deposition and Nitrogen Leaching and Run-off were estimated based on default methodologies presented by 2006 IPCC Guidelines, Eq. 10.27 and 10.29, and the proposed emission factors, Table 11.3. For the estimation of N losses due to volatilisation from manure management Equation 10.26 was used while N losses due to leaching from manure management systems were estimated with Equation 10.28:

- $Frac_{GasMS}$, percent of managed manure nitrogen for livestock category T that volatilises as NH_3 and NO_x in the manure management system S, data from Table 10.22 were utilized (Dairy Cattle: liquid systems: 40%, solid systems: 30%; Other Cattle: 45%, Buffalo: 45%, Sheep: 12%, Swine: liquid systems: 48%, solid systems: 45%; Horses: 12%; Mules and asses: 12%; Goats: 12%; Poultry: 55%, Rabbits: 12%).
- For $Frac_{leachMS}$, percent of managed manure nitrogen losses for livestock category T due to runoff and leaching during solid and liquid storage of manure, data from IPCC Guidelines as mean values were utilized (Dairy Cattle: liquid systems: 0%, solid systems: 10%; Other Cattle: 5%, Buffalo: 5%, Sheep: 3%, Swine: liquid systems: 0%, solid systems: 5%; Horses: 3%; Mules and asses: 3%; Goats: 3%; Poultry: 0%, Rabbits: 0%).

Managed manure N available for application to managed soils, feed, fuel or construction uses were estimated based on Equation 10.34 while $Frac_{LossMS}$, amount of managed manure nitrogen for livestock category T that is lost in the manure management system S, % was calculated based on data from Table 10.23 (Dairy Cattle: liquid systems: 40%, solid systems: 40%; Other Cattle: 50%, Buffalo: 50%, Sheep: 15%, Swine: liquid systems: 48%, solid systems: 50%; Horses: 15%; Mules and asses: 15%; Goats: 15%; Poultry: 55%, Rabbits: 12%) and the proposed figures from IPCC for the amount of nitrogen from bedding (Dairy Cattle: 7 kg N /animal/yr; Other Cattle: 4 kg N /animal/yr, Buffalo: 4 kg N /animal/yr, Sheep: 0.8 kg N /animal/yr, Swine: 1.27 kg N /animal/yr; Horses: 0.8 kg N /animal/yr; Mules and asses: 0.8 kg N /animal/yr; Goats: 0.8 kg N /animal/yr; Poultry: 0 kg N /animal/yr, Rabbits: 0 kg N /animal/yr).

5.3.3 Uncertainties and time-series consistency

The combined uncertainty of CH_4 emissions of manure management sector is estimated at 30.4%. The uncertainty associated with activity data is 5% according to uncertainty given by EL.STAT for the livestock population data. On the other hand, the uncertainty associated with emission factors is 30% as it is estimated according to 2006 IPCC Guidelines.

The combined uncertainty of N_2O emissions of manure management sector is estimated by 100.1%. The uncertainty associated with activity data estimated by 5% (country specific value). The uncertainty associated with emission factors is 100% as it is estimated according to 2006 IPCC Guidelines.

The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the 2006 IPCC Guidelines.

5.3.4 Source-specific QA/QC and verification

Quality control and source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the manure management source are:

1. Investigation for information related to manure management systems applied in Greece per animal species and cross-checking. Information has already sought from the Agricultural University of Athens, the Ministry of Rural Development and Food, the Department of Animal

Production at the School of Agriculture Technology (the Technological Educational Institute of Epirus) and the Office of Rural Development of the Prefecture of Thessaloniki and other research institutes.

2. Comparison of information regarding animal population, agricultural crop production and emissions factors with this of other neighbour countries.

3. Estimations were checked with several calculation tools such as emissions trends and sum deviations.

5.3.5 Recalculations

CH_4 and N_2O emissions from manure management have been included for the 2022 due to updated activity data.

The deviation of CH_4 and N_2O emissions estimated in the current submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 5.20***.

Table 5.20 Recalculations of CH_4 and N_2O emissions from manure management

Year	2022
	CH_4
Difference, in kt CO2 eq	12
Impact on total emissions (excl LULUCF), %	0.016
	N_2O
Difference, in kt CO2 eq	1.77
Impact on total emissions (excl LULUCF), %	0.002

5.3.6 Planned improvements

No modification is planned.

5.4 Rice cultivation (CRF Source Category 3C)

5.4.1 Description

Rice cultivated in Greece is grown in continuously flooded fields. This process results in methane production from anaerobic decomposition of organic matter, and consequently leads to the release of the gas in the atmosphere through the rice plants.

CH_4 emissions from rice cultivation are presented in ***Table 5.21***.

Table 5.21 CH_4 emissions (in Mt eq. CO_2) from rice cultivation

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH_4	0.09	0.08	0.08	0.11	0.13	0.15	0.16	0.16	0.15	0.13	0.11
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH_4	0.12	0.13	0.13	0.13	0.13	0.12	0.14	0.14	0.16	0.17	0.17
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	0.17	0.16	0.15	0.16	0.18	0.18	0.16	0.15	0.15	0.17	0.12
Year	2023										
CH_4	0.12										

CH4 emissions from rice cultivation in 2023 account for 1.47% of total GHG emissions from Agriculture. CH4 emissions increased by 26.9 % in 2023 compared to 1990, with an average annual rate of increase of 0.82% for the period 1990 – 2023.

The fluctuations in emissions trends are attributed to the annual changes in the amount of the cultivated areas as provided by the EL.STAT.

5.4.2 Methodology

In order to estimate methane emissions from rice cultivation, the T1 methodology suggested by the IPCC guidelines was followed. The cultivated areas provided by the EL.STAT and the emission factor 20 g CH_4 / m^2 were used for the emissions calculation.

Rice cultivated in Greece is grown in continuously flooded fields without the use of organic amendments and one cropping period is considered annually.

5.4.3 Uncertainties and time-series consistency

The combined uncertainty of CH_4 emissions of rice cultivation sector is estimated by 40%. The uncertainty associated with activity data is 2% according to uncertainty given by EL.STAT for the for the rice cultivation data. On the other hand, the uncertainty associated with emission factors is 40% as it is estimated according to IPCC Rev. 1996. The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the 2006 IPCC Guidelines.

5.4.4 Recalculations

CH_4 emissions from rice cultivation have been included for 2022 due to updated activity data.

The deviation of CH_4 emissions estimated in the current submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 5.22***.

Table 5.22 Recalculations of CH_4 emissions from rice cultivation

Year	2022
Difference, kt	-35
Impact on total emissions (excl LULUCF), %	-0.045

5.5 Agricultural soils (CRF Source Category 3D)

5.5.1 Description

Agricultural soils constitute the largest anthropogenic source of nitrous oxide emissions. N_2O is produced naturally in soils through the microbial processes of nitrification and denitrification. Agricultural activities add nitrogen to soils, increasing the amount of N_2O released in the atmosphere. Anthropogenic N_2O emissions from agriculture are produced either directly from nitrogen inputs to soils or indirectly, after the removal of nitrogen from soils. The N_2O emissions sources examined are the following:

- Direct N_2O emissions
- Indirect N_2O emissions

Emissions from agricultural soils are presented in ***Table 5.23***.

Table 5.23 N_2O emissions (in kt) from agricultural soils

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Direct emissions	12.53	12.60	12.07	10.71	10.40	10.89	11.00	10.76	10.72	10.49	10.19
Indirect emissions	4.33	4.33	4.17	3.74	3.63	3.81	3.84	3.77	3.76	3.68	3.58
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Direct emissions	10.06	9.94	9.76	9.92	9.40	9.11	9.46	9.01	8.54	9.07	8.56
Indirect emissions	3.54	3.50	3.44	3.48	3.31	3.22	3.34	3.17	3.02	3.20	3.02
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Direct emissions	8.40	8.45	7.85	7.70	7.94	8.07	7.77	7.89	8.18	8.17	7.47
Indirect emissions	2.97	2.97	2.77	2.73	2.80	2.84	2.76	2.80	2.88	2.89	2.66
Year	2023										
Direct emissions	7.49										
Indirect emissions	2.66										

The reduction of N_2O emissions from agricultural soils is mainly due to the reduction in the use of synthetic nitrogen fertilizers. The decrease in the use of synthetic nitrogen fertilizers could probably be attributed to an increase in non fertilized farming, the price of fertilizer and the impact

of initiatives to promote good practice in fertilizer use. Additionally, the annual changes in the amounts of fertilizers used and the agricultural production are the basic factors that account for the fluctuation of emissions during the period 1990 – 2023.

5.5.2 Direct N_2O emissions

Direct N_2O emissions from agricultural soils derive from the following N sources:

- **S**ynthetic N fertilisers (F_{SN})
- Organic N applied as fertiliser (e.g., animal manure, compost, sewage sludge) (F_{ON})
- N in crop residues (above-ground and below-ground), including from N-fixing crops and from forages during pasture renewal (F_{CR})
- N mineralisation associated with loss of soil organic matter resulting from change of land use or management of mineral soils (F_{SOM}),
- Drainage/management of organic soils (i.e., Histosols) 4 (F_{OS}).
- Urine and dung N deposited on pasture, range and paddock by grazing animals (F_{PRP})

To be noted that no Other organic fertilizers (rendering waste, guano, brewery waste, etc.) are applied to soils in Greece based on the official available information. For this reason, for category 3.D.1.b.iii Other organic fertilizers applied to soils, the notation key "NO" is reported.

For the estimation of N_2O emissions Tier 1 methodology suggested by the IPCC 2006 Guidelines was applied, i.e:

$$N_2O\ indirect = (F_{SN}+F_{ON}+F_{CR}+F_{SOM}) \times EF_1 + F_{OS} \times EF_2 + F_{PRP,CPP} \times EF_{3PRP,CPP} + F_{PRP,SO} \times EF_{3PRP,SO}$$

where:

F_{SN} = annual amount of synthetic fertiliser N applied to soils, kg N yr^{-1}

F_{ON} = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils, kg N yr^{-1}

F_{CR} = annual amount of N in crop residues, kg N yr^{-1} (Equation 11.6, IPCC 2006)

F_{SOM} = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1}

F_{OS} = annual area of managed/drained organic soils, ha

F_{PRP} = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr^{-1} (CPP: Cattle, Poultry and Pigs; SO: Sheep and Other animals, respectively)

EF_1 = emission factor for N_2O emissions from N inputs, i.e. 0.01 kg N_2O–N/(kg N)

EF_2 = emission factor for N_2O emissions from drained/managed organic soils, i.e. 8 kg N_2O–N ha^{-1} yr^{-1}.

EF_{3PRP} = emission factor for N_2O emissions from urine and dung N deposited on pasture, range and paddock by grazing animals, kg N_2O–N (kg N input)$^{-1}$ (CPP: Cattle, Poultry and Pigs; SO: Sheep and Other animals, respectively). 0.02 kg N_2O–N/(kg N) for cattle (dairy, non-dairy and buffalo), poultry and pigs and 0.01 kg N_2O–N/(kg N) for other animal.

Synthetic N fertilisers (F_{SN})

As a part of the nitrogen contained in the fertilizer is volatised in ammonia and nitrogen oxides, the relevant conversion factor suggested by IPCC Guidelines. The amount of synthetic nitrogen applied to soils (F_{SN}) and the subsequent N_2O emissions for the period 1990 – 2021 are presented in ***Table 5.24***.

Table 5.24 Synthetic nitrogen applied (in kt) and N_2O emissions (in kt) from synthetic fertilizers, for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	424.00	408.00	390.00	307.00	286.00	316.00	323.00	307.00	308.00	293.00	270.00
N_2O emissions	6.66	6.41	6.13	4.82	4.49	4.97	5.08	4.82	4.84	4.60	4.24
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N input	260.00	253.00	247.00	255.00	224.00	210.00	236.00	201.00	175.00	213.00	181.39
N_2O emissions	4.09	3.98	3.88	4.01	3.52	3.30	3.71	3.16	2.75	3.35	2.85
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N input	175.45	182.53	165.94	164.33	185.02	192.17	179.44	189.75	202.95	208.75	167.42
N_2O emissions	2.76	2.87	2.61	2.58	2.91	3.02	2.82	2.98	3.19	3.28	2.63
Year	2023										
N input	169.01										
N_2O emissions	2.66										

In 2012 and 2013 ERT reviews, recommendation regarding data providers of the annual synthetic fertilizers consumption was arisen emphasizing in the necessity for the collection data from the EL.STAT as an official organization and secondarily by the PHAPFDP.

It must be referred that EL.STAT. issues only import and export data concerning fertilizers and not data concerning specific nitrogen fertilizers consumption in nitrogen units. Therefore, data only from PHAPFDP is able to be collected instead of utilizing imports and export data of fertilizers and assuming nitrogen content.

As far as the information collection methodology is concerned, as it was explained by the experts from PHAPFDP, more than 98% of the Professional Fertilizers Producers & Dealers in Greece are members of the organization. Therefore, information concerning fertilizers consumption as well as the content of each type of fertilizer in nitrogen is provided directly to the association by their members.

Organic N applied as fertiliser ($F_{ON,1}$)

The T1 methodology was also applied for the estimation of N_2O emissions from the use of animal manure as a fertilizing agent. Specifically, the total nitrogen excretion from animals was calculated, as in the case of manure management, and then corrected to account for the fraction that volatises in ammonia and nitrous oxides and the fraction that is deposited in soils through pasture, range and paddock, by using the default emission factors. In ***Table 5.25*** nitrogen input to soils from animal manure ($F_{ON,1}$) and subsequent N_2O emissions are presented, for the period 1990 – 2023.

Table 5.25 Nitrogen input to soils from animal manure (in kt) and N_2O emissions (in kt) from animal manure used as fertilizers

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	70.13	70.52	69.23	69.55	65.91	68.15	68.16	68.24	67.96	67.43	67.81
N_2O emissions	1.10	1.11	1.09	1.09	1.04	1.07	1.07	1.07	1.07	1.06	1.07
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N input	66.90	66.62	66.50	67.11	66.69	66.12	65.85	63.37	61.96	63.83	62.81
N_2O emissions	1.05	1.05	1.04	1.05	1.05	1.04	1.03	1.00	0.97	1.00	0.99
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N	62.82	61.96	59.08	56.15	55.79	55.07	55.31	54.45	55.88	53.83	52.49

input											
N_2O emissions	0.99	0.97	0.93	0.88	0.88	0.87	0.87	0.86	0.88	0.85	0.82
Year	2023										
N input	53.58										
N_2O emissions	0.84										

Application of sewage sludge in agriculture as fertilizer ($F_{ON,2}$)

The application of sewage sludge in agriculture as fertilizer began in 2004 on a limited scale, primarily within research projects and pilot studies; however, its use has since extended beyond these initial efforts. These studies were performed at the period of 2004 to 2006 while for the rest of the years, 2007-2009, significant less experimental efforts were conducted according to Waste management department of the Ministry of Environment and Energy (MEEN).

The N content of sewage sludge (dry matter) used in agriculture is assumed to be 3.0%. This value was obtained from the report 'Disposal and recycling routes for sewage sludge Part 3 – Scientific and technical report', Table 3, Page 24, European Commission, 2001.

Nitrogen input to soils from Sewage sludge ($F_{ON,2}$) used in Agriculture and N_2O emissions from sewage sludge used in Agriculture for the period 1990 – 2023 are presented in ***Table 5.26***.

Table 5.26 Nitrogen input to soils from Sewage sludge used in Agriculture (in kg) and N2O emissions (in t) for the period 1990 – 2021

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N-Sewage sludge											
N_2O emissions											
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
N-Sewage sludge				781.2	829.92	1353.6	7.2	7.2	7.2	6480	4320
N_2O emissions				0.012	0.013	0.021	0.000	0.000	0.000	0.102	0.068
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N-Sewage sludge	224640	541632	545448	543000	341688	179568	507552	512628	538259	118824	563602

N_2O emissions	3.530	8.511	8.571	8.533	5.369	2.822	7.976	8.1	8.5	1.9	9.0
Year	2023										
N-Sewage sludge	591782										
N_2O emissions	9.0										

N in crop residues (F_{CR})

Nitrogen input to soils from Crop residues (F_{CR}) and N2O emissions for the period 1990 – 2023 are presented in ***Table 5.27***. For F_{CR} estimation, parameters from 2006 IPCC Guidelines (vol. 4, table 11.2 are utilized as they are presented in ***Table 5.28***.

Table 5.27 Nitrogen input to soils from Crop residues (in ktn) and N_2O emissions (in t) for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Crop residues	71.3	91.4	78.0	75.4	79.4	75.2	73.5	74.3	70.4	69.6	74.6
N_2O emissions	1.12	1.44	1.23	1.18	1.25	1.18	1.16	1.17	1.11	1.09	1.17
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Crop residues	74.7	73.4	68.2	73.8	73.7	68.8	66.1	76.7	75.7	69.1	70.4
N_2O emissions	1.17	1.15	1.07	1.16	1.16	1.08	1.04	1.21	1.19	1.09	1.11
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Crop residues	69.7	70.3	63.8	59.2	58.6	61.7	51.9	50.5	50.5	49.2	48.7
N_2O emissions	1.10	1.10	1.00	0.93	0.92	0.97	0.82	0.79	0.79	0.77	0.77
Year	2023										
Crop residues	49.0										
N_2O emissions	0.77										

Mineralization/immobilization associated with loss/gain of soil organic matter – N2O (F_{SOM})

It must be mentioned that in accordance with the N mineralized in mineral soils as a result of loss of soil carbon through change in land use or management, i.e. for 5,427,544 kg N/year, 0.085 kt N_2O/year, or 25.41 kt CO_2 eq/year emissions are calculated. This amount is below the significance threshold indicated in paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines, for this reason the emission are reported as not estimated (NE) considered negligible.

Organic soils (F_{OS})

Estimation of N_2O emissions from the organic soils (0.084 kt) was based on the cultivated area (6.7 kHa (F_{OS}), constant for the entire period examined in North Greece) and the updated default emission factor suggested in the 2006 IPCC Guidelines for mid-latitude organic soils. Data for the areas of organic soils derive from a relevant research conducted by the Soil Science Institute of Athens (SSIA, 2001).

Table 5.28 Parameters for FCR estimation

Year	1990 Dry matter fraction of harvested product (DRY)	Cf (IPCC 2006, TABLE 2.6)	Frac_Renew	slope	intercept	NAG	RBG	NBG
Wheat	0.89	0.90	1.00	1.51	0.52	0.006	0.24	0.009
Barley	0.89	0.90	1.00	0.98	0.59	0.007	0.22	0.014
Oats	0.89	0.90	1.00	0.91	0.89	0.007	0.25	0.008
Rye	0.88	0.90	1.00	1.09	0.88	0.005	0.00	0.011
Maize	0.87	0.80	1.00	1.03	0.61	0.006	0.22	0.007
Rice	0.89	0.80	1.00	0.95	2.46	0.007	0.16	0.000
Beans	0.9	0.80	1.00	0.36	0.68	0.010	0.00	0.010
Peas	0.9	0.80	1.00	0.36	0.68	0.010	0.00	0.010
Potatoes	0.22	0.80	1.00	0.1	1.06	0.019	0.20	0.012
Sugarbeet	0.22	0.80	1.00	0.1	1.06	0.019	0.20	0.012
Sorghum	0.89	0.90	1.00	0.89	1.33	0.007	0.24	0.006
Other cereals	0.88	0.90	1.00	1.09	0.88	0.006	0.24	0.009
Veltch	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Bitter Veltch	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Lupine	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Veltching (Lathyrus)	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Clover seeds	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Other	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Groundnuts	0.94	0.80	1.00	1.07	1.54	0.016	0.00	0.000

Soya seed	0.91	0.80	1.00	0.93	1.35	0.008	0.19	0.008
Rapeseed	0.89	0.80	1.00	0.89	1.33	0.007	0.24	0.006
Barley	0.89	0.80	0.25	0.98	0.59	0.007	0.22	0.014
Oats	0.89	0.80	0.25	0.91	0.89	0.007	0.25	0.008
Veltch	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Clovers - Multiannual (alfalfa, etc)	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Clovers - Annual	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Grass cut for hey	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Other	0.9	0.80	0.25	0.3	0	0.027	0.40	0.022
Onions, fresh	0.22	0.80	1.00	0.1	1.06	0.019	0.20	0.014
Onions, dry	0.22	0.80	1.00	0.1	1.06	0.019	0.20	0.014
Garlic, dry	0.22	0.80	1.00	0.1	1.06	0.019	0.20	0.014
Peas	0.91	0.80	1.00	1.13	0.85	0.008	0.19	0.008
Carots	0.22	0.80	1.00	0.1	1.06	0.019	0.20	0.014
Beens	0.91	0.80	1.00	1.13	0.85	0.008	0.19	0.008

Animal production (F_{PRP})

The estimation of N_2O emissions from pasture, range and paddock was based on the methodology used for the calculation of N_2O from manure management (Equation 11.1) using the default factors suggested by IPCC Guidelines (Table 11.1).

Nitrogen input from pasture, range and paddock and N_2O emissions for the period 1990 – 2023 are presented in ***Table 5.29***.

Table 5.29 Nitrogen input (in kt) and N_2O emissions (in kt) from pasture, range and paddock

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
N input	216.84	217.06	216.23	215.92	217.35	220.15	221.24	221.43	222.19	223.08	222.65
N_2O emissions	3.56	3.56	3.54	3.52	3.53	3.59	3.61	3.61	3.63	3.65	3.63
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
N input	225.06	224.98	224.09	220.00	218.10	218.73	218.23	216.84	215.71	215.25	213.70
N_2O	3.67	3.68	3.68	3.62	3.59	3.61	3.59	3.57	3.55	3.55	3.53

Emissions											
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N input	209.93	205.96	194.33	194.91	190.75	190.24	192.77	192.56	194.85	192.63	190.73
N_2O emissions	3.47	3.41	3.22	3.21	3.14	3.13	3.17	3.16	3.23	3.19	3.15
Year	2023										
N input	189.40										
N_2O emissions	3.13										

5.5.3 Indirect N2O emissions

Indirect N_2O emissions from agricultural soils derive from:

- Volatilisation of nitrogen included in synthetic fertilizers, animal manure (used as fertilizer) and sewage sludge (used also as fertilizer) as NO_x and NH_3, followed by atmospheric deposition as NO_x, HNO_3 and NH_4 on soils and surface waters and subsequent N_2O formation.
- Leaching and runoff of nitrogen contained in applied fertilizers (synthetic, animal manure and sewage sludge).

For all sources of N_2O emissions, the Tier 1 methodology suggested by 2006 IPCC Guidelines has been applied (Equations 11.9 and 11.10). The activity data on the amount of nitrogen from synthetic fertilizers, animal manure and sewage sludge are those used for the calculation of direct emissions. The emission factors used are the default ones suggested by IPCC (Table 11.3). The emission factor for atmospheric deposition reflects the fraction of nitrogen that volatiles as ammonia and nitrous oxides, while for leaching and runoff it reflects the fraction of nitrogen that leaks from synthetic fertilizers and animal manure. The amount of nitrogen deposited and the indirect N_2O emissions for the period 1990 – 2023 are presented in ***Table 5.30.***

For the estimation of the fraction of nitrogen that volatilizes as NH_3 and Nox from the input to soils due to the application of sewage sludge in agriculture, the default value suggested by the 2006 IPCC Guidelines, i.e. 20%, was used.

5.5.4 Uncertainties and time-series consistency

The combined uncertainty of N_2O emissions of direct emissions is estimated by 201%. The uncertainty associated with activity data is estimated 20% according to uncertainty given by

EL.STAT for the crop production and the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers for the synthetic fertilizers consumed in the country while the uncertainty associated with emission factors is 200 % (country specific value).

The combined uncertainty of N_2O emissions of indirect emissions is estimated by 53.9%. The uncertainty associated with activity data is 20% according to uncertainty given by EL.STAT for the crop production while the uncertainty associated with emission factors is 50 % as it is estimated according to 2006 IPCC Guidelines.

The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the 2006 IPCC Guidelines.

Table 5.30 Deposited nitrogen (in kt) and indirect N_2O emissions (in kt) from agricultural soils

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Atmospheric deposition											
N deposited	99.79	98.31	96.09	87.79	85.25	89.26	90.18	88.64	88.83	87.40	85.09
N_2O emissions	1.57	1.54	1.51	1.38	1.34	1.40	1.42	1.39	1.40	1.37	1.34
Leaching/ Runoff											
N deposited	234.67	236.08	226.03	200.35	194.58	203.85	205.77	201.29	200.56	195.93	190.52
N_2O emissions	2.77	2.78	2.66	2.36	2.29	2.40	2.43	2.37	2.36	2.31	2.25
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Atmospheric deposition											
N deposited	84.39	83.62	82.82	82.92	79.36	77.97	80.42	76.14	73.03	77.12	73.44
N_2O emissions	1.33	1.31	1.30	1.30	1.25	1.23	1.26	1.20	1.15	1.21	1.15
Leaching/ Runoff											
N	188.00	185.40	181.72	184.79	174.74	169.09	175.86	167.38	158.50	168.36	158.49

deposited											
N_2O emissions	2.22	2.19	2.14	2.18	2.06	1.99	2.07	1.97	1.87	1.98	1.87
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Atmospheric deposition											
N deposited	72.15	71.97	67.41	66.78	67.90	68.32	67.69	68.50	70.57	70.19	65.53
N_2O emissions	1.13	1.13	1.06	1.05	1.07	1.07	1.06	1.08	1.11	1.10	1.03
Leaching/ Runoff											
N deposited	155.47	156.42	145.16	142.59	147.17	149.81	144.02	146.37	151.46	151.37	138.03
N_2O emissions	1.83	1.84	1.71	1.68	1.73	1.77	1.70	1.73	1.79	1.78	1.63
Year	**2023**										
Atmospheric deposition											
N deposited	65.64										
N_2O emissions	1.03										
Leaching/ Runoff											
N deposited	138.52										
N_2O emissions	1.63										

5.5.5 Source-specific QA/QC and verification

Quality control and source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the agricultural soils source are:

1. Cross checking information provided by the National Statistical Service of Greece and by the Pan-Hellenic Association of Professional Fertilizers Producers & Dealers regarding the amount of synthetic fertilizers. Moreover, data provided by FAO for the period 1990-2002 were compared with these provided by PHAPFPD,

2. Comparison of activity data and emissions factors with these of other neighbour countries.

3. Estimations were checked with several calculations tools such as emissions trends and sum deviations.

5.5.6 Recalculations

N_2O emissions from Agricultural soils have been recalculated for 2022 due to updated activity data.

The deviation of N_2O emissions estimated in the current submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 5.31***.

Table 5.31 Recalculations of N_2O emissions from Agricultural soils

Year	2022
Difference, kt	5
Impact on total emissions (excl LULUCF), %	0.007

5.6 Prescribed burning of savannas (CRF Source Category 3E)

No emissions are reported under the category Table 3.E Sectoral background data for agriculture Savannas areas (3E), since Savanas areas are not present in Greece. Therefore, the notation key "NO" is reported for all years of the time series in CRF table.

5.7 Field burning of agricultural residues (CRF Source Category 3F)

5.7.1 Description

The generation of crop residues is a result of the farming practices used. Disposal practices for residues include ploughing them back into the ground, composting, landfilling and burning on-site. It is considered that the residues burned annually on the field comes from the 5% of total cultivated area in Greece. Burning of agricultural residues is responsible for emissions of CH_4, N_2O, CO and NO_x.

CH_4 and N_2O emissions from field burning of agricultural residues are presented in ***Table 5.32***.

Table 5.32 GHG emissions (in kt) from field burning of agricultural residues

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH_4 emissions	1.06	1.09	1.03	1.01	1.00	0.96	0.98	0.98	0.96	0.94	0.97
N_2O emissions	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.03
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
CH_4 emissions	0.96	0.97	0.97	0.98	0.95	0.92	0.89	0.94	1.00	0.88	0.85
N_2O emissions	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CH_4 emissions	0.86	0.84	0.78	0.69	0.70	0.73	0.66	0.64	0.62	0.62	0.61
N_2O emissions	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Year	**2023**										
CH_4 emissions	0.62										
N_2O emissions	0.02										

5.7.2 Methodology

For the estimation of CH_4 and N_2O emissions from field burning of agricultural residues the default methodology by IPCC 2006 Guidelines has been applied.

Equation 2.27 from IPCC 2006 Guidelines is utilized for the estimation of greenhouse gas emissions from fire. Mass of fuel available for combustion is obtained Table 2.4, while combustion factor, from Table 2.6 and emission factor from Table 2.5.

Table 5.33 shows parameters used for their calculation per each crop type for 2023.

Table 5.33 Total biomass burned per each crop type and parameters used for their calculation for 2023

	MB (tn/ha)	Cf	Gef CO_2 g/kg dry matter	Gef CO g/kg dry matter	Gef CH_4 g/kg dry matter	Gef N_2O g/kg dry matter	Gef NOx g/kg dry matter
Wheat	4	0.90	1515	92	2.7	0.07	2.5
Barley	4	0.90	1515	92	2.7	0.07	2.5
Oats	4	0.80	1515	92	2.7	0.07	2.5
Rye	4	0.80	1515	92	2.7	0.07	2.5
Maize	10	0.80	1515	92	2.7	0.07	2.5
Rice	5.5	0.80	1515	92	2.7	0.07	2.5
Beans	6.5	0.80	1515	92	2.7	0.07	2.5
Peas	6.5	0.80	1515	92	2.7	0.07	2.5
Potatoes	6.5	0.80	1515	92	2.7	0.07	2.5
Sugarbeet	6.5	0.80	1515	92	2.7	0.07	2.5
Sorghum	4	0.80	1515	92	2.7	0.07	2.5
Other	4	0.80	1515	92	2.7	0.07	2.5
Veltch	4	0.80	1515	92	2.7	0.07	2.5
Bitter Veltch	4	0.80	1515	92	2.7	0.07	2.5
Lupine	4	0.80	1515	92	2.7	0.07	2.5
Veltching (Lathyrus)	4	0.80	1515	92	2.7	0.07	2.5
Clover seeds	4	0.80	1515	92	2.7	0.07	2.5
Other	4	0.80	1515	92	2.7	0.07	2.5
Groundnuts	4	0.80	1515	92	2.7	0.07	2.5
Soya seed	4	0.80	1515	92	2.7	0.07	2.5
Rapeseed	4	0.80	1515	92	2.7	0.07	2.5
Barley	4	0.80	1515	92	2.7	0.07	2.5
Oats	4	0.80	1515	92	2.7	0.07	2.5
Veltch	4	0.80	1515	92	2.7	0.07	2.5
Clovers - Multiannual (alfalfa, etc)	4	0.80	1515	92	2.7	0.07	2.5
Clovers - Annual	4	0.80	1515	92	2.7	0.07	2.5
Grass cut for hey	4	0.80	1515	92	2.7	0.07	2.5
Other	4	0.80	1515	92	2.7	0.07	2.5
Onions, fresh	6.5	0.80	1515	92	2.7	0.07	2.5
Onions, dry	6.5	0.80	1515	92	2.7	0.07	2.5
Garlic, dry	6.5	0.80	1515	92	2.7	0.07	2.5
Peas	6.5	0.80	1515	92	2.7	0.07	2.5
Carots	6.5	0.80	1515	92	2.7	0.07	2.5
Beens	6.5	0.80	1515	92	2.7	0.07	2.5

5.7.3 Uncertainties and time-series consistency

The combined uncertainty of CH_4 emissions of field burning of agricultural sector is estimated by 28.3%. The combined uncertainty of N_2O emissions of field burning of agricultural sector is estimated by 28.3%. The uncertainty associated with activity data is 20% according to uncertainty given by EL.STAT for for the crop production data while the uncertainty associated with emission factors is 20% as it is estimated according to 2006 IPCC Guidelines.

The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the 2006 IPCC Guidelines.

5.7.4 Recalculations

CH_4 and N_2O emissions from field burning for 2022 have been recalculated due to updated activity data.

The deviation of CH_4 and N_2O emissions from field burning in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 5.34.***

Table 5.34 Recalculations of CH_4 and N_2O emissions from field burning

Year	2022
	CH_4
Difference, kt	0.18
Impact on total emissions (excl LULUCF), %	0.00028
	N_2O
Difference, kt	0.04
Impact on total emissions (excl LULUCF), %	6e-5

5.8 Liming (CRF Source Category 3G)

No emissions are reported under the category Table 3.G Liming, since nor Limestone $CaCO_3$ neither Dolomite $CaMg(CO_3)_2$ are applied in agriculture sector in Greece. Therefore, the notation key "NO" is reported for all years of the time series in CRF table.

The information that liming is not practised in the country is provided by the Pan-Hellenic Association of Professional Producers and Dealers of Fertilizer, the most relevant data provider in relation to information on fertilizers in the national inventory team, who confirmed that neither limestone nor dolomite are used in Greece for agricultural purposes.

To be noted that Liming of soils is applied to some extent in croplands, mainly in the west of the country, that face more soil acidification problems. However, oxide (CaO) and hydroxide (Ca(OH)2) of lime are used for this purpose - rather than carbonate containing lime - that do not result in emissions of CO2 when applied to soil. These materials are proved to be more efficient, since limestone (CaCO3) has large diameter that result in small / slow dissolubility under the Greek dry conditions. CO2 is produced in the production of lime and hydrated lime, but these emissions are estimated and reported under the Industrial Processes Sector.

5.9 Urea application (CRF Source Category 3H)

5.9.1 Description

Adding urea to soils during fertilisation leads to a loss of CO_2 that was fixed in the industrial production process. Urea ($CO(NH_2)_2$) is converted into ammonium (NH4+), hydroxyl ion (OH-), and bicarbonate (HCO_3-), in the presence of water and urease enzymes. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO_2 and water.

CO_2 Urea application for the period 1990 – 2023 are presented in ***Table 5.35***.

Table 5.35 GHG emissions (in kt) from Urea application

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2 emissions	60	58	56	44	41	45	46	44	44	42	38
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2 emissions	37	36	35	36	32	30	34	29	25	30	26
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2 emissions	25	26	26	23	26	34	33	35	37	38	31
Year	2023										
CO_2 emissions	31										

5.9.2 Methodology

For the estimation of CO_2 emissions from Urea application the default methodology suggested in IPCC Guidelines has been applied. The emission factors used are the default ones suggested by IPCC Guidelines.

5.9.3 Uncertainties and time-series consistency

The combined uncertainty of CO_2 emissions of Urea application is estimated by 53.9%. The uncertainty associated with activity data is 20% while the uncertainty associated with emission factors is 50%.

The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the 2006 IPCC Guidelines.

5.9.4 Recalculations

No recalculation was performed.

6. Land Use, Land Use Change and Forestry (CRT sector 4)

6.1 Overview

This chapter involves emissions and removals of greenhouse gases from the Land Use, Land-Use Change and Forestry sector. It describes the methodologies used to estimate emissions/removals by each source/sink category. Emissions and removals from this sector have been calculated using the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry, and Other Land Use (henceforth in this chapter 2006 GL AFOLU), in accordance with the decision 24/CP.19, the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (henceforth KP Supplement) and the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (henceforth in this chapter GPG LULUCF), adopted at COP9 (Decision 13/CP.9). The GPG LULUCF introduced new categories for estimating and reporting emissions and removals of CO_2 and other greenhouse gases, based on six top-level land-use[2] categories:

- Forest land
- Cropland
- Grassland
- Wetlands
- Settlements
- Other land

The 2005 inventory submission included the results of Greece's first attempt to comply with the reporting requirements of Decision 13/CP.9 for the LULUCF sector. Carbon stock changes in five carbon pools (Aboveground Biomass, Belowground Biomass, Dead Wood, Litter and Soil Organic Matter) and emissions of non-CO_2 gases were assessed and reported. Specific quality assurance and quality control procedures were followed in the preparation of this inventory, uncertainties were estimated, and key categories were identified. However, GHG emissions and removals for several land use and land use change categories were not estimated until the 2010 submission. The 2010 submission incorporated some major improvements undertaken by Greece to improve accuracy and completeness of the reported estimates, to minimize uncertainties and to be compliant with the reporting requirements of both UNFCCC and the KP, while from 2015 and onwards the national inventory report is following methodologies provided in the 2006 GL AFOLU, and KP Supplement.

The 2024 submission included improvements pertinent to Regulations (EU) 2018/841, 2018/1999 and Regulation (EU) 2023/839 *"of the European Parliament and of the Council of 19 April 2023 amending Regulation (EU) 2018/841 as regards the scope, simplifying the reporting and*

[2] The names of these land categories are a mixture of land cover (e.g., Forest land, Grassland, Wetlands) and land use (e.g., Cropland, Settlements) classes, however, for convenience, they are here referred to as land-use categories.

compliance rules, and setting out the targets of the Member States for 2030, and Regulation (EU) 2018/1999 as regards improvement in monitoring, reporting, tracking of progress and review."

Geographically explicit data to track land use changes and SOC estimates for cropland were first incorporated in the 2023 submission, whereas litter and dead wood estimates for FL were included in the 2024 NIR submission.

The remainder of this chapter is organized as follows. Paragraph 6.1 continues with an overview of the LULUCF sector with a presentation of emission/removal levels and trends, a brief discussion on the methodology used in this inventory, an assessment of the completeness of the GHG inventory for the LULUCF sector and the presentation of recalculations and improvements undertaken since the previous submission. Then, relevant information on the land-use definitions and the classification system used as well as information on approaches used for representing land areas is given in the next two paragraphs, 6.2 and 6.3. Finally, in Paragraphs 6.4 to 6.11 detailed information (descriptions, references and sources of specific methodologies, assumptions, emission factors and activity data used and the rational for their selection) on each category is presented.

6.1.1 Emissions/Removals trends

The Land Use, Land-Use Change and Forestry sector was a net sink of greenhouse gases during the period 1990 – 2023. The sink capacity of the LULUCF sector fluctuates between -2.0 Mt CO_2 eq and -5.18 Mt CO_2 eq, showing an increasing trend. This is the result of the increase of the sink capacity of the Forest Land and Grassland category.

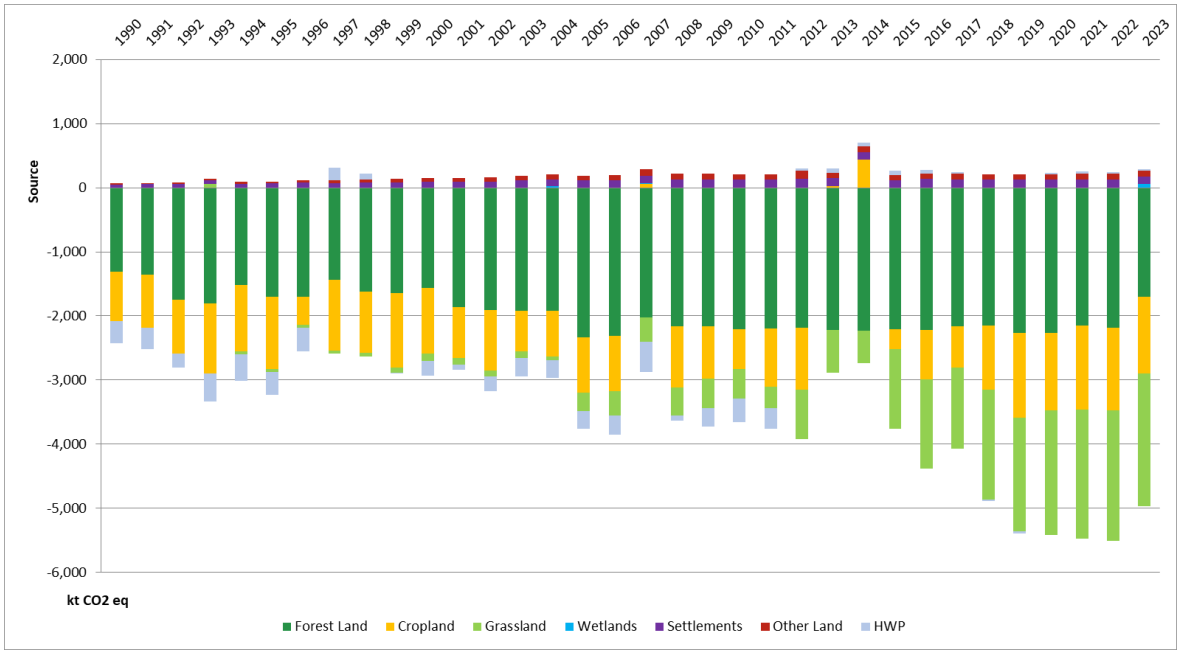


Figure 6.1 Net GHG emissions / removals (in kt CO_2 eq) from the Land Use, Land Use Change and Forestry sector by category for the period 1990 – 2023

Net carbon removals were reduced in 2023 due to extreme events. Extended wildfires in Rhodes and the national park of Dadia burned more than 185.000 hectares in August 2023, leading to the reduction of living biomass and increase of non-CO2 emissions from Forest Land. Normally, the impact of the large wildfires of 2023 would be reported after a decade according to the stock change method applied by Greece, incorporating also gains from regeneration. However, due to the severity of these events, it was considered safer to include reductions in the gains in living biomass at this point to reflect these losses in the trend. Moreover, in September severe storms hit Thessaly, leading to the inundation of the Cropland surrounding lake Karla for several months.

CO_2 is the main greenhouse gas emitted to and removed from the atmosphere following carbon stocks changes in different carbon pools. Non-CO_2 greenhouse gases (CH_4 and N_2O) and indirect GHG (NO_x and CO) are released in relatively small quantities when biomass is burnt.

As shown in ***Figure 6.1***, Forest land category acts as net carbon sinks during the period 1990 – 2023. Emissions/removals from the Forest land category are the result of the balance mainly in biomass increment from forest growth and biomass loss due to fellings and wildfires. Net removals from Forest land show an upward trend that is attributed mainly to the reduction in fellings, increase of stand age due to sustainable forest management and rehabilitation of coppices to high forest. The sink capacity of Forest land has thus increased from -1.31 Mt CO_2 eq in 1990 to -2.19 Mt CO_2 eq in 2023.

Removals from Cropland, fluctuate between -0.31 to -1.32 Mt CO_2 eq yr^{-1} (except 2007, 2013 and 2014 where the category acts as a source).

Grassland category appears as a sink from 1994 –2023 mainly due to the conversion of Cropland to Grassland, while emissions from that category are primarily the result of conversion of Forest land to Grassland and changes in vegetation type (shrubland to grassland), as well as the result of wildfires. The conversion of Forest land and Grassland to Wetlands, Settlements and Other Land categories produces small amounts of CO_2. Emissions/removals per gas and category from LULUCF are presented in ***Table 6.1***.

Table 6.1 GHG emissions/removals (in kt) from the Land Use, Land Use Change and Forestry sector by category and gas for the period 1990-2023

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Net CO_2 emissions / removals (in kt)																	
A. Forest Land	-1310.03	-1361.31	-1744.18	-1800.06	-1517.88	-1702.53	-1700.03	-1439.25	-1623.93	-1639.54	-1563.20	-1864.95	-1903.54	-1920.06	-1922.27	-2332.64	-2312.66
B. Cropland	-766.27	-826.13	-841.75	-1097.68	-1038.66	-1131.24	-436.37	-1100.65	-946.10	-1160.68	-1024.59	-788.34	-948.41	-628.01	-713.04	-860.97	-860.53
C. Grassland	0.22	0.20	1.49	54.87	-44.49	-42.76	-48.26	-47.73	-64.87	-88.45	-109.12	-109.13	-91.20	-106.83	-59.52	-287.22	-375.40
D. Wetlands	NE,NO	NE,NO	0.04	0.70	0.26	0.08	0.20	0.57	2.16	0.33	2.51	0.74	2.38	1.37	26.31	3.10	4.25
E. Settlements	49.74	54.76	55.07	58.80	62.90	64.24	77.95	72.54	75.52	81.96	89.96	89.58	94.25	111.79	106.05	115.06	115.37
F. Other Land	19.79	12.68	29.99	23.60	26.41	27.89	39.44	44.87	46.20	51.52	59.15	64.23	69.89	69.09	77.69	69.91	82.51
G. HWPs	-348.99	-331.53	-217.35	-431.16	-411.30	-350.81	-369.92	198.08	96.06	-10.85	-235.04	-81.68	-230.43	-288.56	-265.63	-283.85	-305.34
CH_4 emissions (in kt)																	
A. Forest Land	1.88	0.71	2.06	2.15	1.88	1.24	0.51	1.50	4.72	0.30	5.84	0.62	0.06	0.09	0.23	0.20	0.58
B. Cropland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C. Grassland	0.63	0.53	1.61	1.13	1.18	0.50	0.54	0.81	1.59	0.18	2.48	0.50	0.09	0.13	0.31	0.23	0.25
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWPs																	
N_2O emissions (in kt)																	
A. Forest Land	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.03	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
B. Cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
C. Grassland	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00
D. Wetlands	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E. Settlements	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
F. Other Land	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
G. HWPs																	
TOTAL LULUCF (kt CO2 eq)	-2279.61	-2412.13	-2604.37	-3089.61	-2827.54	-3078.82	-2400.45	-2196.63	-2220.27	-2744.08	-2523.73	-2646.56	-2992.17	-2743.79	-2722.39	-3551.69	-3613.71

Note: Negative (-) sign denotes GHG removals and positive sign (+) GHG emissions

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Net CO_2 emissions / removals (in kt)																	
A. Forest Land	-2024.17	-2158.56	-2164.17	-2203.51	-2194.52	-2186.24	-2216.81	-2226.69	-2206.44	-2213.79	-2157.20	-2152.88	-2269.63	-2261.99	-2153.03	-2187.65	-1700.33
B. Cropland	62.76	-952.94	-811.10	-623.28	-910.32	-965.09	26.45	438.48	-307.71	-774.15	-642.43	-994.40	-1318.57	-1206.88	-1311.37	-1278.99	-1199.43
C. Grassland	-378.79	-444.78	-457.88	-464.69	-333.55	-773.60	-670.40	-512.62	-1250.63	-1392.83	-1276.18	-1711.81	-1770.62	-1944.13	-2011.39	-2040.82	-2071.00
D. Wetlands	3.60	2.84	2.84	2.63	2.61	2.90	2.61	0.22	0.20	0.17	0.16	0.38	1.74	1.12	2.39	1.01	53.07
E. Settlements	119.25	121.08	122.24	121.34	119.89	131.89	121.00	118.99	120.37	133.56	131.49	131.71	125.95	124.65	124.63	130.02	125.36
F. Other Land	107.50	99.33	89.72	86.45	84.33	128.23	82.43	82.47	80.15	81.38	83.76	79.02	75.65	76.59	96.76	89.01	87.52
G. HWPs	-467.99	-76.05	-291.13	-363.88	-323.95	35.62	64.45	67.32	65.79	64.34	23.59	-32.13	-32.48	28.10	27.88	27.66	27.44
CH_4 emissions (in kt)																	
A. Forest Land	7.71	1.20	1.31	0.55	0.24	0.88	0.07	0.04	0.17	0.49	0.22	0.16	0.83	0.33	5.09	1.99	17.00
B. Cropland	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
C. Grassland	5.14	0.54	0.54	0.10	0.48	0.87	0.57	0.33	0.26	0.78	0.52	0.62	2.28	0.42	0.40	0.23	2.05
D. Wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
E. Settlements	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
F. Other Land	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. HWPs																	
N_2O emissions (in kt)																	
A. Forest Land	0.05	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.01	0.09
B. Cropland	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C. Grassland	0.04	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.01
D. Wetlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
E. Settlements	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
F. Other Land	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
G. HWPs																	
TOTAL LULUCF (kt CO2 eq)	-2180.56	-3342.41	-3439.29	-3410.99	-3520.49	-3560.11	-2557.62	-2007.41	-3472.35	-4050.74	-3802.04	-4644.11	-5082.41	-5147.27	-5046.51	-5180.49	-4103.01

Note: Negative (-) sign denotes GHG removals and positive sign (+) GHG emissions

6.1.2 Methodology

The estimation of GHG emissions from Land Use, Land Use Change and Forestry is based on the methodologies and assumptions suggested by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Agriculture, Forestry, and Other Land Use, the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol, and the IPCC Good Practice Guidance for LULUCF.

Activity data and country specific emission/removal factors were obtained from the Hellenic Statistical Authority (ELSTAT), the Ministry of Environment and Energy (MEEN), the Greek Payment Authority of Common Agricultural Policy Aid Schemes (OPEKEPE) and relevant studies of research bodies. References to all sources are given in the description of the methodology used in each category.

The methodology applied for the calculation of emissions per source / sink category is summarised in ***Table 6.2,*** while a detailed description is given in the respective chapters for each category.

Table 6.2 Methodology for the estimation of emissions/removals from the LULUCF sector

IPCC Source / Sink Categories	CO_2		CH_4		N_2O	
	Method	Emission factor	Method	Emission factor	Method	Emission factor
A. Forest Land						
A1. Forest Land remaining Forest Land	T1,T2	CS, D	T1	D	T1	D
A2. Land converted to Forest Land	T1,T2	OTH,D	T1	D	T1	D
B. Cropland						
B1. Cropland remaining Cropland	T1,T2	CS, D	NA	NA	NA	NA
B2. Land converted to Cropland	T1,T2	CS, D	NA	NA	T1	D
C. Grassland						
C1. Grassland remaining Grassland	T1,T2	CS	T1	D	T1	D
C2. Land converted to Grassland	T1,T2	CS, D	NA	NA	T1	D
D. Wetlands						
D1. Wetlands remaining Wetlands						
D2. Land converted to Wetlands	T1,T2	CS, D	NA	NA	T1	D
E. Settlements						
E1. Settlements remaining Settlements)						
E2. Land converted to Settlements	T1,T2	CS, D	NA	NA	T1	D
F. Other Land						
F1. Other Land remaining Other Land						
F2. Land converted to Other Land	T1,T2	CS, D	NA	NA	T1	D
G. Harvested wood products	T2	D	NA	NA	NA	NA

T1. T2: IPCC methodology Tier 1 and Tier 2 respectively
CS: Country specific methodology and emission factor
OTH: Other

D: IPCC default methodology and emission factor

In this inventory, the IPCC default land use transition period of 20 years was used in the estimation process of carbon stock changes in mineral soils related to land use changes, with the only exception to be that in Land converted to Wetlands. Following previous ERT's recommendation and in order to increase transparency the transition period that has been applied to estimate carbon stock changes in each land use change category is presented below:

LULUCF	**Transition period**
Land converted to Forest land	
Cropland converted to Forest land	*20 years*
Grassland converted to Forest land	*20 years*
Land converted to Cropland	
Forest land converted to Cropland	*20 years*
Grassland converted to Cropland	*20 years*
Land Converted to Wetlands	
Forest land converted to Wetlands	*10 years*[3]
Grassland converted to Wetlands	*10 years*[2]
Land converted to Settlements	
Forest land converted to Settlements	*20 years*
Grassland converted to Settlements	*20 years*
Land converted to Other land	
Forest land converted to Other land	*20 years*
Grassland converted to Other land	*20 years*

Key categories

Key categories – a term introduced by the GPG LULUCF to expand key source concept and cover both source and sink categories – have been determined following the Tier 1 method. The key categories in the *LULUCF* sector determined by this analysis are presented in ***Table 6.3*** (see Paragraph 1.5 for a complete presentation of the results of the key category analysis and Annex I for the presentation of the relevant calculations).

Table 6.3 Key categories in the LULUCF sector in 2023

IPCC source / sink category	Greenhouse Gas	Level assessment	Trend assessment
Forest Land remaining Forest Land	CO_2	☒	☒
Cropland remaining Cropland	CO_2		☒
Land converted to Grassland	CO_2	☒	☒
Harvested Wood Products	CO_2		☒

[3] According to Appendix 3a.3 of the GPG LULUCF (Tier 1), 10 years is the time period for which emissions from soil organic matter pool have been assumed to occur after flooding took place.

Uncertainty

The results of the uncertainty analysis undertaken for the Greek GHG emissions inventory are presented in Paragraph 1.7, while the detailed calculations are presented in Annex IV. More information is also given in the respective sub-chapters in this section.

6.1.3 Completeness

The completeness of the inventory for the sector Land use, Land Use-Change and Forestry is summarized in ***Table 6.4*** below.

Table 6.4 Land Use, Land Use Change and Forestry – Completeness of emissions / removals inventory

IPCC source / sink categories	CO_2	CH_4	N_2O
A. Forest Land			
1. Forest Land remaining Forest Land	☑	☑	☑
2. Land converted to Forest Land	☑	☑	☑
B. Cropland			
1. Cropland remaining Cropland	☑	NO	NO
2. Land converted to Cropland	☑	NO	☑
C. Grassland			
1. Grassland remaining Grassland	☑	☑	☑
2. Land converted to Grassland	☑	NO	☑
D. Wetlands			
1. Wetlands remaining Wetlands			
2. Land converted to Wetlands	☑	NO	☑
E. Settlements			
1. Settlements remaining Settlements			
2. Land converted to Settlements	☑	NO	☑
F. Other Land			
1. Other Land remaining Other Land			
2. Land converted to Other Land	☑	NO	☑
G. Harvested wood products	☑	NO	NO

NO: Not Occurring

6.1.4 Category-specific QA/QC procedures

Category specific quality control is carried out based on the principles of inventory Quality Assurance/Quality Control (QA/QC) plan. The special procedures followed in the LULUCF sector are:

- Cross-checking information provided by the Forest Service of each prefecture and by the central Forest Service regarding the area of wildfires, managed forest and the land use changes.

- Cross-checking information provided by ELSTATand OPEKEPE
- Comparison of information regarding the emissions factors with this of other neighbor countries.
- Investigation of more information related to cropland management practices applied in Greece.
- Identification and detection of exceptional net emissions/removals in the GHG trends.
- Estimations were cross-checked several times with the aim of ensuring the accuracy of the results.
- Cross-checks of information provided in the NIR and the CRT tables.

The most important results of the internal audits are:

- Need for continuous cross-checking of data provided from the local Forest Services to the central Forest Service in order to identify and correct any discrepancies and/or data entry errors. Need for a more automated procedure for data entry.
- Need for continuous cross-checking of data provided by ELSTAT, OPEKEPE and MEEN in order to identify internal inconsistencies.
- Need to establish a national database of geographically explicit information regarding land use, land use change and forest vegetation.
- Need to seek additional sources of information regarding grassland areas and management practices in Greece.
- More efforts need to be done in order to collect country specific data with the aim of increasing the Tier level of estimations of emissions/removals resulting from carbon stock changes in the various carbon pools in key land use categories.
- Need for improvements in the description in the NIR of methods, activity data and emission factors used for the estimation of emissions/removals from different sources/sinks, and better implementation of the annotated NIR, in order to further improve transparency.
- Better use of notation keys in the CRT tables. Especially reporting complete information in CRT table 9.
- Need for continuous cross-checking of information provided in the NIR and the CRT tables.
- Investigation of the process chain of HWPs in the country for a more comprehensive interpretation of the net emissions trend in this pool.

6.1.5 Recalculations and improvements

The current submission includes significant recalculations for living biomass in the Cropland remaining Cropland category across the timeseries. The recalculations were carried out based on data from ELSTAT, following the completion of the agricultural inventory in 2021 and the agricultural statistics for 2022 that were published in 2024. Moreover, information from the Ministry of Agriculture for the period 2000 – 2018 have been considered, as well as data from OPEKEPE. More information is included in chapter 6.3.3. Additional improvements are planned that will lead to recalculations, described in the following chapter (6.1.6)

6.1.6 Planned improvements

Greece has prioritized the improvement of its MRV system in compliance with Regulations (EU) 2018/841 and (EU) 2018/1999 in its updated National Energy and Climate Plan (2025)[4]. The planned actions aim to improve the transparency, consistency and accuracy of the reporting focusing on:

1. Land representation

   Description: Implementation of approach 3. Incorporation of spatially-explicit land-use and land-use conversion data over the entire time-series, for all land-use categories and sub-categories.

   Current status: Greece has already started compiling the available geospatial data to plan specific actions, in conjunction with the ongoing forest inventory which is expected to be completed in 2025.

   Planned implementation: 2028 submission

2. Land transition matrix

   Description: Update of the land transition matrix as follows:

   i) Implementation of 30-year transition period for Grassland converted to Forest Land

   ii) Cropland converted to Forest Land re-transition to Cropland after 20 years, in compliance with EEC Regulations 2080/92 and 1257/99 that apply 20 year funding plans

   Current status: Planned

   Planned implementation: 2026 submission

3. Forest land

[4] https://commission.europa.eu/publications/greece-final-updated-necp-2021-2030-submitted-2025_en

3.1 FRL technical correction

Description: Technical correction for FRL to include the dead wood and litter pools that have been added to the NIR and incorporate changes in the GWP for CH4 and N2O according to the AR5.

Current status: On-going

Planned implementation: 2026 submission

3.2 Unmanaged Forest Land inclusion

Description: Reporting the entire area of Forest land as "managed", divided into forest types, following the on-going reform of the forestry sector in Greece. The legislative framework to extend management to all public forests, as well as the operation of a digital platform for FMP data are being planned.

Current status: Planned to begin after the inventory and monitoring system for forests and wooded land is established and the final results become available for the entire country, in 2025.

Planned implementation: 2028 submission. More accurate areas of forest land remaining forest land using available geospatial data, starting from 1985, will be calculated and disaggregated information on forests will be provided by forest type

4. Cropland

4.1 Geographically explicit crop area information

Description: Calculation of more accurate areas for each crop type, based on geographically explicit data from OPEKEPE at parcel level, to improve accuracy starting from 2009 to improve accuracy. Recalculations using splicing techniques will be applied for the period 1990-2008 to ensure consistency.

Current status: On-going

Planned implementation: 2028 submission

4.2 Categorization of olive groves

Description: Categorization of olive groves in different subtypes (old trees, modern olive fields etc.) and estimate carbon stocks for each category to improve accuracy.

Current status: On-going. Up-to-date data from OPEKEPE made available for 2023, which will be correlated with numerical data from 2017.

Planned implementation: 2028 submission

5. Grassland

   Description: Calculation of CSC in living biomass, DOM and soils for the Grassland remaining Grassland category (Tier 2)

   Current status: Planned

   Planned implementation: 2028 submission

6. HWP

   Description: Reduction of large inter-annual variations in the removals from HWP produced and consumed domestically (particularly between the years 1998 and 1999, 1999 and 2000, and 2008 and 2009)

   Current status: On-going. The large inter-annual variations are attributed to the import quantities provided by FAO, which are based on estimated values for these years (https://www.fao.org/faostat/en/#data/FO). Recalculations will be performed to reduce the inter-annual variation using linear interpolation for the years in question. Proxy data or other statistics are being investigated to apply splicing techniques.

   Planned implementation: 2026 submission

6.2 Land-use definitions and classification systems used and their correspondence to the LULUCF categories

The forest definition of Greece in this inventory is the same used in the previous inventories and adopted also in the framework of the Kyoto Protocol. It includes productive and non-productive forests, and transitional woodlands.

The threshold values for tree crown cover, land area and tree height are:

i. 25% minimum tree crown cover.

ii. 0.3 hectares minimum land area.

iii. 2 metres tree height, or the potential to achieve it.

Cropland category includes all annual and perennial crops as well as temporary fallow land.

Grassland includes rangeland and pasture with vegetation that falls below the threshold of forest definition and are not expected to exceed it without human intervention.

Wetlands include land that is covered or saturated by water for all or the greatest part of the year (e.g. lakes, reservoirs, marshes), as well as river bed (including torrent beds) and that does not fall into the forest land, cropland, grassland or settlements categories.

Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included in other land-use categories.

The category of "Other land" includes all land areas that do not fall into any of other land-use categories (e.g. rocky areas, bare soil).

The land use and land-use change matrices for the period 1990 to 2023 are presented below, both as annual and 20-years matrices. The methodology applied for their development is described in the following chapter.

Table 6.5 Annual and 20-years land use, and land-use change matrices (areas in ha)

	from/to	1990						*Total 1989*
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1989	Forest land	3.359.072	NO	1	NO	6	107	3.359.186
	Cropland	NO	3.941.859	NO	NO	2.341	NO	3.944.200
	Grassland	3.993	2.341	4.792.581	NO	448	231	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	0	265.280	265.280
	Total 1990	3.363.065	3.944.200	4.792.581	299.600	533.116	265.618	13.198.180

	from/to	1990						*Total 1971*
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1971	Forest land	3.359.072	NO	1	NO	6	107	3.359.186
	Cropland	NO	3.941.859	NO	NO	2.341	NO	3.944.200
	Grassland	3.993	2.341	4.792.581	NO	448	231	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	NO	265.280	265.280
	Total 1990	3.363.065	3.944.200	4.792.581	299.600	533.116	265.618	13.198.180

	from/to	1991						*Total 1990*
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1990	Forest land	3.363.018	0	NO	NO	16	31	3.363.065
	Cropland	NO	3.941.859	NO	NO	2.341	NO	3.944.200
	Grassland	3.925	2.341	4.785.996	NO	171	148	4.792.581
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	533.116	NO	533.116
	Other land	NO	NO	NO	NO	2	265.616	265.618
	Total 1991	3.366.943	3.944.200	4.785.996	299.600	535.647	265.794	13.198.180

	from/to	1991						*Total 1972*
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1972	Forest land	3.359.025	NO	1	NO	22	138	3.359.186
	Cropland	NO	3.939.517	NO	NO	4.683	NO	3.944.200
	Grassland	7.918	4.682	4.785.995	NO	620	379	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	2	265.278	265.280
	Total 1991	3.366.943	3.944.200	4.785.996	299.600	535.647	265.794	13.198.180

1991	from/to	1992 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1991
	Forest land	3.366.751	1	2	2	13	174	3.366.943
	Cropland	NO	3.941.195	663	NO	2.341	NO	3.944.200
	Grassland	4.071	4	4.781.638	NO	66	218	4.785.996
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	535.647	NO	535.647
	Other land	NO	NO	NO	NO	1	265.794	265.794
	Total 1992	3.370.822	3.941.200	4.782.304	299.602	538.067	266.185	13.198.180

1973	from/to	1992 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1973
	Forest land	3.358.833	2	3	2	35	312	3.359.186
	Cropland	NO	3.936.512	663	NO	7.024	NO	3.944.200
	Grassland	11.989	4.686	4.781.638	NO	686	596	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	2	265.278	265.280
	Total 1992	3.370.822	3.941.200	4.782.304	299.602	538.067	266.185	13.198.180

1992	from/to	1993 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1992
	Forest land	3.369.962	1	767	NO	17	74	3.370.822
	Cropland	NO	3.919.487	19.372	NO	2.341	NO	3.941.200
	Grassland	4.738	12	4.777.345	32	42	135	4.782.304
	Wetlands	NO	NO	NO	299.602	NO	NO	299.602
	Settlements	NO	NO	NO	NO	538.067	NO	538.067
	Other land	NO	NO	NO	NO	1	266.184	266.185
	Total 1993	3.374.700	3.919.500	4.797.484	299.634	540.470	266.393	13.198.180

1974	from/to	1993 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1974
	Forest land	3.357.973	3	770	2	52	386	3.359.186
	Cropland	NO	3.914.800	20.035	NO	9.366	NO	3.944.200
	Grassland	16.727	4.697	4.776.679	32	728	731	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	4	265.276	265.280
	Total 1993	3.374.700	3.919.500	4.797.484	299.634	540.470	266.393	13.198.180

1993	from/to	1994 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1993
	Forest land	3.374.616	0	4	1	20	58	3.374.700
	Cropland	2.400	3.912.898	1.861	NO	2.341	NO	3.919.500
	Grassland	1.562	2	4.795.673	1	84	161	4.797.484
	Wetlands	NO	NO	NO	299.634	NO	NO	299.634
	Settlements	NO	NO	NO	NO	540.470	NO	540.470
	Other land	NO	NO	NO	NO	1	266.392	266.393
	Total 1994	3.378.579	3.912.900	4.797.538	299.636	542.916	266.611	13.198.180

1975	from/to	1994 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1975
	Forest land	3.357.890	3	774	3	72	444	3.359.186
	Cropland	2.400	3.908.197	21.896	NO	11.707	NO	3.944.200
	Grassland	18.289	4.699	4.774.869	33	812	892	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	5	265.275	265.280
	Total 1994	3.378.579	3.912.900	4.797.538	299.636	542.916	266.611	13.198.180

1994	from/to	1995 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1994
	Forest land	3.378.295	2	189	NO	13	79	3.378.579
	Cropland	3.200	3.906.093	1.265	NO	2.341	NO	3.912.900
	Grassland	962	5	4.796.481	0	24	65	4.797.538
	Wetlands	NO	NO	NO	299.636	NO	NO	299.636
	Settlements	NO	NO	NO	NO	542.916	NO	542.916
	Other land	NO	NO	NO	NO	0	266.611	266.611
	Total 1995	3.382.457	3.906.100	4.797.936	299.636	545.295	266.755	13.198.180

1976	from/to	1995 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1976
	Forest land	3.357.606	5	963	3	86	523	3.359.186
	Cropland	5.600	3.901.390	23.161	NO	14.048	NO	3.944.200
	Grassland	19.251	4.704	4.773.812	33	836	957	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	5	265.275	265.280
	Total 1995	3.382.457	3.906.100	4.797.936	299.636	545.295	266.755	13.198.180

1995	from/to	1996 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1995
	Forest land	3.382.073	1	79	5	143	156	3.382.457
	Cropland	3.000	3.898.696	2.062	NO	2.341	NO	3.906.100
	Grassland	1.263	2	4.796.452	NO	23	196	4.797.936
	Wetlands	NO	NO	NO	299.636	NO	NO	299.636
	Settlements	NO	NO	NO	NO	545.295	NO	545.295
	Other land	NO	NO	NO	NO	4	266.751	266.755
	Total 1996	3.386.336	3.898.700	4.798.593	299.641	547.806	267.104	13.198.180

1977	from/to	1996 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1977
	Forest land	3.357.222	7	1.041	8	228	679	3.359.186
	Cropland	8.600	3.893.987	25.224	NO	16.390	NO	3.944.200
	Grassland	20.514	4.707	4.772.328	33	859	1.153	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	9	265.271	265.280
	Total 1996	3.386.336	3.898.700	4.798.593	299.641	547.806	267.104	13.198.180

1996	from/to	1997 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1996
	Forest land	3.386.203	NO	0	NO	10	122	3.386.336
	Cropland	6.000	3.883.499	6.859	NO	2.341	NO	3.898.700
	Grassland	0	1	4.798.166	22	54	351	4.798.593
	Wetlands	NO	NO	NO	299.641	NO	NO	299.641
	Settlements	NO	NO	NO	NO	547.806	NO	547.806
	Other land	NO	NO	NO	NO	2	267.102	267.104
	Total 1997	3.392.203	3.883.500	4.805.026	299.663	550.213	267.574	13.198.180

1978	from/to	1997 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1978
	Forest land	3.357.089	7	1.042	8	238	802	3.359.186
	Cropland	14.600	3.878.786	32.083	NO	18.731	NO	3.944.200
	Grassland	20.514	4.708	4.771.901	55	912	1.504	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	11	265.269	265.280
	Total 1997	3.392.203	3.883.500	4.805.026	299.663	550.213	267.574	13.198.180

1997	from/to	1998 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1997
	Forest land	3.392.112	1	2	NO	15	73	3.392.203
	Cropland	1.800	3.872.099	7.260	NO	2.341	NO	3.883.500
	Grassland	181	0	4.804.434	93	38	280	4.805.026
	Wetlands	NO	NO	NO	299.663	NO	NO	299.663
	Settlements	NO	NO	NO	NO	550.213	NO	550.213
	Other land	NO	NO	NO	NO	34	267.541	267.574
	Total 1998	3.394.093	3.872.100	4.811.696	299.756	552.641	267.894	13.198.180

1979	from/to	1998 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1979
	Forest land	3.356.998	7	1.044	8	253	875	3.359.186
	Cropland	16.400	3.867.385	39.343	NO	21.073	NO	3.944.200
	Grassland	20.695	4.708	4.771.309	148	950	1.784	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	45	265.235	265.280
	Total 1998	3.394.093	3.872.100	4.811.696	299.756	552.641	267.894	13.198.180

1998	from/to	1999 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1998
	Forest land	3.393.971	2	6	NO	37	76	3.394.093
	Cropland	4.000	3.861.197	4.562	NO	2.341	NO	3.872.100
	Grassland	NO	1	4.811.312	NO	103	280	4.811.696
	Wetlands	NO	NO	NO	299.756	NO	NO	299.756
	Settlements	NO	NO	NO	NO	552.641	NO	552.641
	Other land	NO	NO	NO	NO	20	267.874	267.894
	Total 1999	3.397.971	3.861.200	4.815.880	299.756	555.142	268.230	13.198.180

1980	from/to	1999 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1980
	Forest land	3.356.876	9	1.050	8	291	951	3.359.186
	Cropland	20.400	3.856.481	43.905	NO	23.414	NO	3.944.200
	Grassland	20.695	4.709	4.770.925	148	1.053	2.063	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	64	265.216	265.280
	Total 1999	3.397.971	3.861.200	4.815.880	299.756	555.142	268.230	13.198.180

1999	from/to	2000 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1999
	Forest land	3.397.788	NO	NO	NO	78	105	3.397.971
	Cropland	2.377	3.856.482	NO	NO	2.341	NO	3.861.200
	Grassland	1.685	2.818	4.810.996	100	169	112	4.815.880
	Wetlands	NO	NO	NO	299.756	NO	NO	299.756
	Settlements	NO	NO	NO	NO	555.142	NO	555.142
	Other land	NO	NO	NO	NO	3	268.228	268.230
	Total 2000	3.401.850	3.859.300	4.810.996	299.856	557.733	268.445	13.198.180

1981	from/to	2000 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1981
	Forest land	3.356.693	9	1.050	8	369	1.057	3.359.186
	Cropland	22.777	3.851.763	43.905	NO	25.755	NO	3.944.200
	Grassland	22.380	7.528	4.766.041	248	1.222	2.175	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	67	265.213	265.280
	Total 2000	3.401.850	3.859.300	4.810.996	299.856	557.733	268.445	13.198.180

2000	from/to	2001 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 2000
	Forest land	3.401.659	2	NO	NO	38	151	3.401.850
	Cropland	1.026	3.855.902	NO	NO	2.372	NO	3.859.300
	Grassland	3.043	3.096	4.804.591	9	83	173	4.810.996
	Wetlands	NO	NO	NO	299.856	NO	NO	299.856
	Settlements	NO	NO	NO	NO	557.733	NO	557.733
	Other land	NO	NO	NO	NO	1	268.444	268.445
	Total 2001	3.405.729	3.859.000	4.804.591	299.865	560.227	268.768	13.198.180

1982	from/to	2001 Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	Total 1982
	Forest land	3.356.502	11	1.050	8	407	1.207	3.359.186
	Cropland	23.803	3.848.365	43.905	NO	28.128	NO	3.944.200
	Grassland	25.423	10.624	4.759.636	257	1.305	2.348	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	68	265.212	265.280
	Total 2001	3.405.729	3.859.000	4.804.591	299.865	560.227	268.768	13.198.180

	from/to	2002						Total 2001
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2001	Forest land	3.405.557	1	1	18	38	114	3.405.729
	Cropland	905	3.845.997	9.726	NO	2.372	NO	3.859.000
	Grassland	3.145	2	4.801.045	0	143	256	4.804.591
	Wetlands	NO	NO	NO	299.865	NO	NO	299.865
	Settlements	NO	NO	NO	NO	560.227	NO	560.227
	Other land	NO	NO	NO	NO	1	268.767	268.768
	Total 2002	3.409.607	3.846.000	4.810.772	299.883	562.781	269.136	13.198.180

	from/to	2002						Total 1983
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1983	Forest land	3.356.331	12	1.051	26	445	1.321	3.359.186
	Cropland	24.708	3.835.362	53.631	NO	30.500	NO	3.944.200
	Grassland	28.568	10.626	4.756.091	257	1.448	2.604	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	69	265.211	265.280
	Total 2002	3.409.607	3.846.000	4.810.772	299.883	562.781	269.136	13.198.180

	from/to	2003						Total 2002
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2002	Forest land	3.409.264	2	13	16	218	95	3.409.607
	Cropland	3.090	3.826.595	13.942	NO	2.372	NO	3.846.000
	Grassland	1.131	3	4.809.170	5	237	226	4.810.772
	Wetlands	NO	NO	NO	299.883	NO	NO	299.883
	Settlements	NO	NO	NO	NO	562.781	NO	562.781
	Other land	NO	NO	NO	NO	1	269.136	269.136
	Total 2003	3.413.486	3.826.600	4.823.125	299.904	565.609	269.457	13.198.180

	from/to	2003						Total 1984
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1984	Forest land	3.355.988	14	1.064	42	663	1.416	3.359.186
	Cropland	27.798	3.815.957	67.573	NO	32.872	NO	3.944.200
	Grassland	29.700	10.629	4.754.488	262	1.685	2.830	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	69	265.211	265.280
	Total 2003	3.413.486	3.826.600	4.823.125	299.904	565.609	269.457	13.198.180

	from/to	2004						Total 2003
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2003	Forest land	3.413.207	NO	7	20	85	167	3.413.486
	Cropland	2.400	3.761.090	60.738	NO	2.372	NO	3.826.600
	Grassland	1.757	10	4.819.918	1.132	147	161	4.823.125
	Wetlands	NO	NO	NO	299.904	NO	NO	299.904
	Settlements	NO	NO	NO	NO	565.609	NO	565.609
	Other land	NO	NO	NO	NO	7	269.450	269.457
	Total 2004	3.417.364	3.761.100	4.880.663	301.056	568.220	269.777	13.198.180

	from/to	2004						Total 1985
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1985	Forest land	3.355.709	14	1.071	62	748	1.583	3.359.186
	Cropland	30.199	3.750.447	128.311	NO	35.244	NO	3.944.200
	Grassland	31.457	10.639	4.751.282	1.394	1.832	2.991	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	76	265.204	265.280
	Total 2004	3.417.364	3.761.100	4.880.663	301.056	568.220	269.777	13.198.180

	from/to	2005						Total 2004
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2004	Forest land	3.417.261	NO	NO	NO	62	42	3.417.364
	Cropland	1.828	3.733.699	23.200	NO	2.372	NO	3.761.100
	Grassland	2.154	1	4.878.025	9	398	77	4.880.663
	Wetlands	NO	NO	NO	301.056	NO	NO	301.056
	Settlements	NO	NO	NO	NO	568.220	NO	568.220
	Other land	NO	NO	NO	NO	NO	269.777	269.777
	Total 2005	3.421.243	3.733.700	4.901.226	301.064	571.052	269.896	13.198.180

	from/to	2005						Total 1986
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1986	Forest land	3.355.605	14	1.071	62	810	1.624	3.359.186
	Cropland	32.027	3.723.046	151.511	NO	37.616	NO	3.944.200
	Grassland	33.611	10.640	4.748.644	1.403	2.230	3.068	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	76	265.204	265.280
	Total 2005	3.421.243	3.733.700	4.901.226	301.064	571.052	269.896	13.198.180

	from/to	2006						Total 2005
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2005	Forest land	3.421.089	NO	1	13	58	81	3.421.243
	Cropland	1.245	3.722.198	7.885	NO	2.372	NO	3.733.700
	Grassland	2.788	2	4.897.847	7	264	318	4.901.226
	Wetlands	NO	NO	NO	301.064	NO	NO	301.064
	Settlements	NO	NO	NO	NO	571.052	NO	571.052
	Other land	NO	NO	NO	NO	0	269.895	269.896
	Total 2006	3.425.121	3.722.200	4.905.733	301.085	573.746	270.295	13.198.180

	from/to	2006						Total 1987
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1987	Forest land	3.355.451	14	1.072	75	868	1.705	3.359.186
	Cropland	33.272	3.711.544	159.396	NO	39.988	NO	3.944.200
	Grassland	36.398	10.642	4.745.265	1.410	2.494	3.386	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	76	265.204	265.280
	Total 2006	3.425.121	3.722.200	4.905.733	301.085	573.746	270.295	13.198.180

	from/to	2007						Total 2006
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2006	Forest land	3.424.637	NO	2	4	81	397	3.425.121
	Cropland	NO	3.702.493	17.335	NO	2.372	NO	3.722.200
	Grassland	4.363	7	4.900.993	4	163	203	4.905.733
	Wetlands	NO	NO	NO	301.085	NO	NO	301.085
	Settlements	NO	NO	NO	NO	573.746	NO	573.746
	Other land	NO	NO	NO	NO	2	270.292	270.295
	Total 2007	3.429.000	3.702.500	4.918.330	301.093	576.365	270.893	13.198.180

	from/to	2007						Total 1988
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1988	Forest land	3.354.967	14	1.074	79	950	2.103	3.359.186
	Cropland	33.272	3.691.837	176.731	NO	42.360	NO	3.944.200
	Grassland	40.761	10.648	4.740.525	1.414	2.656	3.589	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	79	265.201	265.280
	Total 2007	3.429.000	3.702.500	4.918.330	301.093	576.365	270.893	13.198.180

	from/to	2008						Total 2007
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2007	Forest land	3.428.842	NO	2	NO	75	80	3.429.000
	Cropland	244	3.693.809	6.074	NO	2.372	NO	3.702.500
	Grassland	3.792	1	4.914.095	NO	123	318	4.918.330
	Wetlands	NO	NO	NO	301.093	NO	NO	301.093
	Settlements	NO	NO	NO	NO	576.365	NO	576.365
	Other land	NO	NO	NO	NO	2	270.891	270.893
	Total 2008	3.432.878	3.693.810	4.920.172	301.093	578.938	271.289	13.198.180

	from/to	2008						Total 1989
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1989	Forest land	3.354.809	14	1.077	79	1.025	2.183	3.359.186
	Cropland	33.516	3.683.147	182.805	NO	44.732	NO	3.944.200
	Grassland	44.554	10.649	4.736.290	1.414	2.780	3.907	4.799.594
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	530.320	NO	530.320
	Other land	NO	NO	NO	NO	81	265.199	265.280
	Total 2008	3.432.878	3.693.810	4.920.172	301.093	578.938	271.289	13.198.180

	from/to	2009						Total 2008
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2008	Forest land	3.432.799	NO	39	NO	13	27	3.432.878
	Cropland	199	3.685.348	5.892	NO	2.372	NO	3.693.810
	Grassland	3.760	2	4.916.200	NO	122	88	4.920.172
	Wetlands	NO	NO	NO	301.093	NO	NO	301.093
	Settlements	NO	NO	NO	NO	578.938	NO	578.938
	Other land	NO	NO	NO	NO	NO	271.289	271.289
	Total 2009	3.436.757	3.685.350	4.922.131	301.093	581.445	271.404	13.198.180

	from/to	2009						Total 1990
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1990	Forest land	3.358.722	14	1.116	79	1.032	2.103	3.363.065
	Cropland	33.714	3.677.026	188.697	NO	44.763	NO	3.944.200
	Grassland	44.321	8.310	4.732.319	1.414	2.453	3.765	4.792.581
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	533.116	NO	533.116
	Other land	NO	NO	NO	NO	81	265.537	265.618
	Total 2009	3.436.757	3.685.350	4.922.131	301.093	581.445	271.404	13.198.180

	from/to	2010						Total 2009
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2009	Forest land	3.436.721	0	5	NO	2	29	3.436.757
	Cropland	NO	3.670.916	12.062	NO	2.372	NO	3.685.350
	Grassland	3.914	14	4.917.875	NO	250	78	4.922.131
	Wetlands	NO	NO	NO	301.093	NO	NO	301.093
	Settlements	NO	NO	NO	NO	581.445	NO	581.445
	Other land	NO	NO	NO	NO	NO	271.404	271.404
	Total 2010	3.440.635	3.670.930	4.929.942	301.093	584.069	271.511	13.198.180

	from/to	2010						Total 1991
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1991	Forest land	3.362.612	14	1.120	79	1.018	2.101	3.366.943
	Cropland	33.714	3.664.933	200.759	NO	44.794	NO	3.944.200
	Grassland	44.309	5.983	4.728.063	1.414	2.532	3.695	4.785.996
	Wetlands	NO	NO	NO	299.600	NO	NO	299.600
	Settlements	NO	NO	NO	NO	535.647	NO	535.647
	Other land	NO	NO	NO	NO	79	265.715	265.794
	Total 2010	3.440.635	3.670.930	4.929.942	301.093	584.069	271.511	13.198.180

	from/to	2011						Total 2010
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2010	Forest land	3.406.871	NO	NO	NO	8	42	3.406.921
	Cropland	NO	3.600.849	101.424	NO	2.372	NO	3.704.644
	Grassland	3.397	17	4.926.441	NO	82	5	4.929.942
	Wetlands	NO	NO	NO	301.093	NO	NO	301.093
	Settlements	NO	NO	NO	NO	584.069	NO	584.069
	Other land	NO	NO	NO	NO	0	271.511	271.511
	Total 2011	3.410.268	3.600.866	5.027.865	301.093	586.531	271.558	13.198.180

	from/to	2011						Total 1992
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1992	Forest land	3.366.632	13	1.118	77	1.013	1.968	3.370.822
	Cropland	34.246	3.560.611	301.519	NO	44.824	NO	3.941.200
	Grassland	43.636	5.996	4.725.227	1.414	2.547	3.483	4.782.304
	Wetlands	NO	NO	NO	299.602	NO	NO	299.602
	Settlements	NO	NO	NO	NO	538.067	NO	538.067
	Other land	NO	NO	NO	NO	79	266.107	266.185
	Total 2011	3.444.514	3.566.620	5.027.865	301.093	586.531	271.558	13.198.180

	from/to	2012						Total 2011
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2011	Forest land	3.443.938	NO	2	6	115	453	3.444.514
	Cropland	NO	3.559.999	4.249	NO	2.372	NO	3.566.620
	Grassland	4.455	1	5.023.064	1	295	49	5.027.865
	Wetlands	NO	NO	NO	301.093	NO	NO	301.093
	Settlements	NO	NO	NO	NO	586.531	NO	586.531
	Other land	NO	NO	NO	NO	NO	271.558	271.558
	Total 2012	3.448.393	3.560.000	5.027.315	301.099	589.313	272.060	13.198.180

	from/to	2012						Total 1993
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1993	Forest land	3.370.794	12	353	83	1.112	2.347	3.374.700
	Cropland	34.246	3.554.003	286.397	NO	44.855	NO	3.919.500
	Grassland	43.353	5.986	4.740.565	1.383	2.800	3.397	4.797.484
	Wetlands	NO	NO	NO	299.634	NO	NO	299.634
	Settlements	NO	NO	NO	NO	540.470	NO	540.470
	Other land	NO	NO	NO	NO	77	266.316	266.393
	Total 2012	3.448.393	3.560.000	5.027.315	301.099	589.313	272.060	13.198.180

	from/to	2013						Total 2012
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2012	Forest land	3.448.356	NO	NO	NO	20	17	3.448.393
	Cropland	NO	3.516.063	41.565	NO	2.372	NO	3.560.000
	Grassland	3.915	17	5.023.313	NO	59	11	5.027.315
	Wetlands	NO	NO	NO	301.099	NO	NO	301.099
	Settlements	NO	NO	NO	NO	589.313	NO	589.313
	Other land	NO	NO	NO	NO	NO	272.060	272.060
	Total 2013	3.452.271	3.516.080	5.064.877	301.099	591.765	272.087	13.198.180

	from/to	2013						Total 1994
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1994	Forest land	3.374.720	11	349	82	1.111	2.306	3.378.579
	Cropland	31.846	3.510.068	326.100	NO	44.886	NO	3.912.900
	Grassland	45.705	6.001	4.738.428	1.382	2.775	3.247	4.797.538
	Wetlands	NO	NO	NO	299.636	NO	NO	299.636
	Settlements	NO	NO	NO	NO	542.916	NO	542.916
	Other land	NO	NO	NO	NO	76	266.535	266.611
	Total 2013	3.452.271	3.516.080	5.064.877	301.099	591.765	272.087	13.198.180

	from/to	2014						Total 2013
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2013	Forest land	3.452.240	NO	NO	NO	3	28	3.452.271
	Cropland	NO	3.328.842	184.866	NO	2.372	NO	3.516.080
	Grassland	3.910	28	5.060.887	NO	15	38	5.064.877
	Wetlands	NO	NO	NO	301.099	NO	NO	301.099
	Settlements	NO	NO	NO	NO	591.765	NO	591.765
	Other land	NO	NO	NO	NO	NO	272.087	272.087
	Total 2014	3.456.150	3.328.870	5.245.752	301.099	594.155	272.153	13.198.180

	from/to	2014						Total 1995
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1995	Forest land	3.378.851	9	160	82	1.101	2.254	3.382.457
	Cropland	28.646	3.322.837	509.701	NO	44.917	NO	3.906.100
	Grassland	48.653	6.024	4.735.892	1.382	2.766	3.220	4.797.936
	Wetlands	NO	NO	NO	299.636	NO	NO	299.636
	Settlements	NO	NO	NO	NO	545.295	NO	545.295
	Other land	NO	NO	NO	NO	76	266.679	266.755
	Total 2014	3.456.150	3.328.870	5.245.752	301.099	594.155	272.153	13.198.180

	from/to	2015						Total 2014
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2014	Forest land	3.456.123	NO	NO	NO	5	21	3.456.150
	Cropland	NO	3.282.520	43.978	NO	2.372	NO	3.328.870
	Grassland	3.905	NO	5.241.759	NO	78	11	5.245.752
	Wetlands	NO	NO	NO	301.099	NO	NO	301.099
	Settlements	NO	NO	NO	NO	594.155	NO	594.155
	Other land	NO	NO	NO	NO	NO	272.153	272.153
	Total 2015	3.460.028	3.282.520	5.285.737	301.099	596.610	272.185	13.198.180

	from/to	2015						Total 1996
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1996	Forest land	3.383.087	8	81	77	964	2.119	3.386.336
	Cropland	25.646	3.276.490	551.617	NO	44.947	NO	3.898.700
	Grassland	51.295	6.021	4.734.039	1.382	2.821	3.035	4.798.593
	Wetlands	NO	NO	NO	299.641	NO	NO	299.641
	Settlements	NO	NO	NO	NO	547.806	NO	547.806
	Other land	NO	NO	NO	NO	72	267.032	267.104
	Total 2015	3.460.028	3.282.520	5.285.737	301.099	596.610	272.185	13.198.180

	from/to	2016						Total 2015
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2015	Forest land	3.459.821	NO	3	NO	139	64	3.460.028
	Cropland	NO	3.254.072	26.076	NO	2.372	NO	3.282.520
	Grassland	4.085	8	5.281.364	NO	238	41	5.285.737
	Wetlands	NO	NO	NO	301.099	NO	NO	301.099
	Settlements	NO	NO	NO	NO	596.610	NO	596.610
	Other land	NO	NO	NO	NO	NO	272.185	272.185
	Total 2016	3.463.907	3.254.080	5.307.444	301.099	599.360	272.290	13.198.180

	from/to	2016						Total 1997
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1997	Forest land	3.388.881	8	84	77	1.093	2.061	3.392.203
	Cropland	19.646	3.248.043	570.833	NO	44.978	NO	3.883.500
	Grassland	55.381	6.029	4.736.526	1.359	3.006	2.725	4.805.026
	Wetlands	NO	NO	NO	299.663	NO	NO	299.663
	Settlements	NO	NO	NO	NO	550.213	NO	550.213
	Other land	NO	NO	NO	NO	70	267.504	267.574
	Total 2016	3.463.907	3.254.080	5.307.444	301.099	599.360	272.290	13.198.180

	from/to	2017						Total 2016
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2016	Forest land	3.463.765	1	7	NO	74	61	3.463.907
	Cropland	NO	3.134.685	117.023	NO	2.372	NO	3.254.080
	Grassland	4.021	4	5.302.888	NO	350	181	5.307.444
	Wetlands	NO	NO	NO	301.099	NO	NO	301.099
	Settlements	NO	NO	NO	NO	599.360	NO	599.360
	Other land	NO	NO	NO	NO	0	272.290	272.290
	Total 2017	3.467.785	3.134.690	5.419.918	301.099	602.157	272.531	13.198.180

	from/to	2017						Total 1998
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1998	Forest land	3.390.720	8	88	77	1.152	2.048	3.394.093
	Cropland	17.846	3.128.649	680.597	NO	45.009	NO	3.872.100
	Grassland	59.220	6.033	4.739.233	1.267	3.318	2.626	4.811.696
	Wetlands	NO	NO	NO	299.756	NO	NO	299.756
	Settlements	NO	NO	NO	NO	552.641	NO	552.641
	Other land	NO	NO	NO	NO	37	267.857	267.894
	Total 2017	3.467.785	3.134.690	5.419.918	301.099	602.157	272.531	13.198.180

	from/to	2018						Total 2017
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2017	Forest land	3.467.644	1	7	2	70	62	3.467.785
	Cropland	NO	3.096.914	35.404	NO	2.372	NO	3.134.690
	Grassland	3.956	0	5.415.185	93	463	220	5.419.918
	Wetlands	NO	NO	NO	301.099	NO	NO	301.099
	Settlements	NO	NO	NO	NO	602.157	NO	602.157
	Other land	NO	NO	NO	NO	0	272.531	272.531
	Total 2018	3.471.600	3.096.915	5.450.596	301.194	605.062	272.813	13.198.180

	from/to	2018						Total 1999
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
1999	Forest land	3.394.579	7	89	78	1.185	2.033	3.397.971
	Cropland	13.846	3.090.876	711.439	NO	45.039	NO	3.861.200
	Grassland	63.176	6.032	4.739.068	1.359	3.678	2.567	4.815.880
	Wetlands	NO	NO	NO	299.756	NO	NO	299.756
	Settlements	NO	NO	NO	NO	555.142	NO	555.142
	Other land	NO	NO	NO	NO	17	268.213	268.230
	Total 2018	3.471.600	3.096.915	5.450.596	301.194	605.062	272.813	13.198.180

	from/to	2019						Total 2018
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2018	Forest land	3.471.532	0	23	8	30	7	3.471.600
	Cropland	NO	3.047.486	47.057	NO	2.372	NO	3.096.915
	Grassland	4.035	42	5.445.770	7	214	528	5.450.596
	Wetlands	NO	NO	NO	301.194	NO	NO	301.194
	Settlements	NO	NO	NO	NO	605.062	NO	605.062
	Other land	NO	NO	NO	NO	NO	272.813	272.813
	Total 2019	3.475.567	3.047.528	5.492.851	301.208	607.678	273.347	13.198.180

	from/to	2019						Total 2000
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2000	Forest land	3.398.572	7	112	86	1.137	1.935	3.401.850
	Cropland	11.469	3.044.265	758.496	NO	45.070	NO	3.859.300
	Grassland	65.526	3.256	4.734.242	1.266	3.724	2.982	4.810.996
	Wetlands	NO	NO	NO	299.856	NO	NO	299.856
	Settlements	NO	NO	NO	NO	557.733	NO	557.733
	Other land	NO	NO	NO	NO	15	268.430	268.445
	Total 2019	3.475.567	3.047.528	5.492.851	301.208	607.678	273.347	13.198.180

	from/to	2020						Total 2019
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2019	Forest land	3,475,370	1	28	NO	49	119	3,475,567
	Cropland	NO	3,026,033	19,123	NO	2,372	NO	3,047,528
	Grassland	3,975	2,830	5,485,622	100	198	125	5,492,851
	Wetlands	NO	NO	NO	301,208	NO	NO	301,208
	Settlements	NO	NO	NO	NO	607,678	NO	607,678
	Other land	NO	NO	NO	NO	NO	273,347	273,347
	Total 2020	3,479,346	3,028,865	5,504,773	301,308	610,297	273,592	13,198,180

	from/to	2020						Total 2001
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2001	Forest land	3,402,445	7	140	86	1,148	1,903	3,405,729
	Cropland	10,443	3,025,868	777,619	NO	45,070	NO	3,859,000
	Grassland	66,458	2,989	4,727,014	1,357	3,839	2,934	4,804,591
	Wetlands	NO	NO	NO	299,865	NO	NO	299,865
	Settlements	NO	NO	NO	NO	560,227	NO	560,227
	Other land	NO	NO	NO	NO	14	268,754	268,768
	Total 2020	3,479,346	3,028,865	5,504,773	301,308	610,297	273,592	13,198,180

	from/to	2021						Total 2020
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2020	Forest land	3,479,089	6	13	0	41	198	3,479,346
	Cropland	NO	3,016,309	10,108	45	2,403	NO	3,028,865
	Grassland	5,173	3,232	5,495,197	52	92	1,027	5,504,773
	Wetlands	NO	NO	NO	301,308	NO	NO	301,308
	Settlements	NO	NO	NO	NO	610,297	NO	610,297
	Other land	NO	NO	NO	NO	47	273,544	273,592
	Total 2021	3,484,262	3,019,546	5,505,318	301,406	612,880	274,769	13,198,180

	from/to	2021						Total 2002
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2002	Forest land	3,406,238	11	152	69	1,150	1,987	3,409,607
	Cropland	9,538	3,013,315	778,001	45	45,101	NO	3,846,000
	Grassland	68,486	6,219	4,727,165	1,408	3,788	3,706	4,810,772
	Wetlands	NO	NO	NO	299,883	NO	NO	299,883
	Settlements	NO	NO	NO	NO	562,781	NO	562,781
	Other land	NO	NO	NO	NO	60	269,076	269,136
	Total 2021	3,484,262	3,019,546	5,505,318	301,406	612,880	274,769	13,198,180

	from/to	2022						Total 2021
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2021	Forest land	3,483,982	4	24	18	106	128	3,484,262
	Cropland	NO	2,998,550	18,586	3	2,407	NO	3,019,546
	Grassland	6,992	155	5,497,590	8	224	349	5,505,318
	Wetlands	NO	NO	NO	301,406	NO	NO	301,406
	Settlements	NO	NO	NO	NO	612,880	NO	612,880
	Other land	NO	NO	NO	NO	4	274,765	274,769
	Total 2022	3,490,974	2,998,708	5,516,201	301,434	615,621	275,241	13,198,180

	from/to	2022						Total 2003
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2003	Forest land	3,410,180	14	164	70	1,039	2,020	3,413,486
	Cropland	6,447	2,992,324	782,645	48	45,136	NO	3,826,600
	Grassland	74,347	6,371	4,733,392	1,411	3,775	3,829	4,823,125
	Wetlands	NO	NO	NO	299,904	NO	NO	299,904
	Settlements	NO	NO	NO	NO	565,609	NO	565,609
	Other land	NO	NO	NO	NO	64	269,393	269,457
	Total 2022	3,490,974	2,998,708	5,516,201	301,434	615,621	275,241	13,198,180

	from/to	2023						Total 2022
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2022	Forest land	3,490,625	2	13	19	219	96	3,490,974
	Cropland	NO	2,966,483	19,362	10,469	2,394	NO	2,998,708
	Grassland	4,503	18	5,511,087	5	331	258	5,516,201
	Wetlands	NO	NO	NO	301,434	NO	NO	301,434
	Settlements	NO	NO	NO	NO	615,621	NO	615,621
	Other land	NO	NO	NO	NO	3	275,238	275,241
	Total 2022	3,495,129	2,966,503	5,530,462	311,927	618,569	275,591	13,198,180

	from/to	2023						Total 2004
		Forestland	Cropland	Grassland	Wetlands	Settlements	Other land	
2004	Forest land	3,413,989	16	169	69	1,173	1,949	3,417,364
	Cropland	4,033	2,960,122	741,269	10,517	45,158	NO	3,761,100
	Grassland	77,107	6,365	4,789,023	285	3,958	3,925	4,880,663
	Wetlands	NO	NO	NO	301,056	NO	NO	301,056
	Settlements	NO	NO	NO	NO	568,220	NO	568,220
	Other land	NO	NO	NO	NO	60	269,717	269,777
	Total 2022	3,495,129	2,966,503	5,530,462	311,927	618,569	275,591	13,198,180

Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

The various forms of land use in 2023 are presented in ***Figure 6.2***

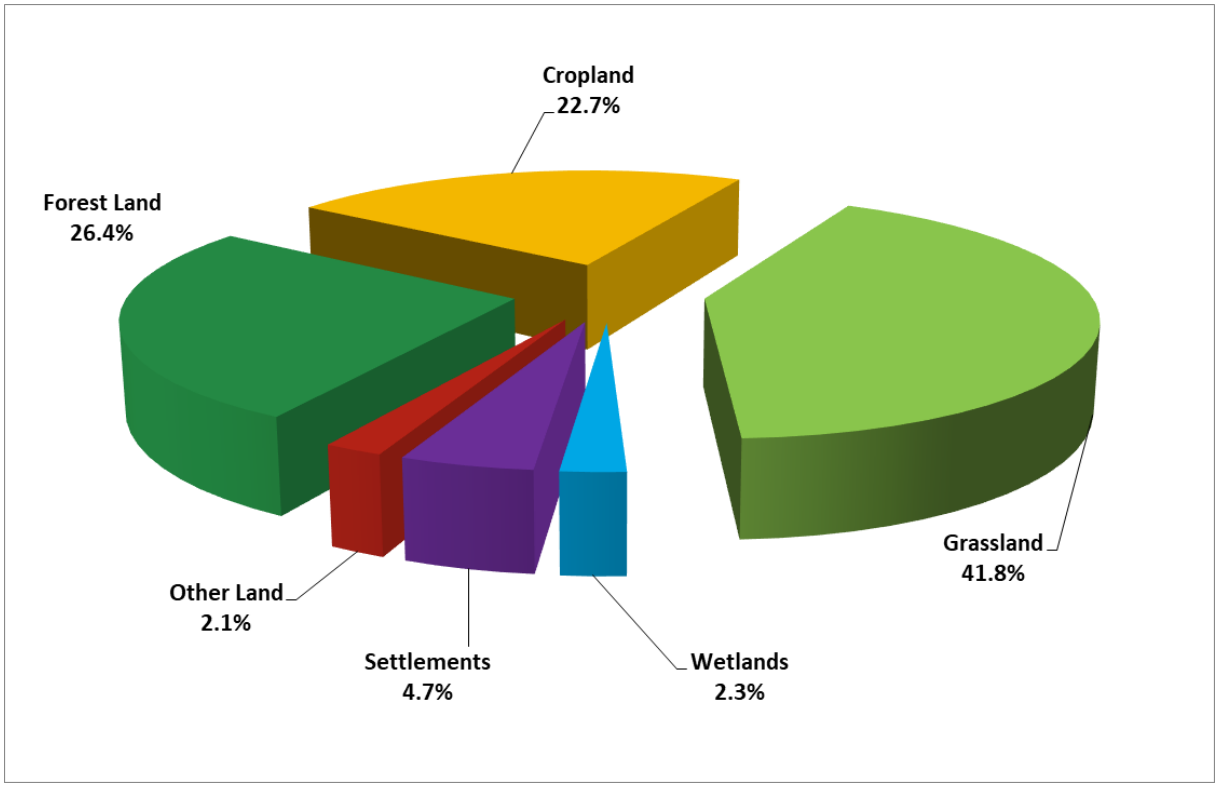


Figure 6.2 Distribution of the area of Greece in 2023 by land-use category

The information used for the representation of land areas was the following:

- the first National Forest Inventory (1st NFI) prepared by the General Secretariat of Forests and Natural Environment (GSFNE, 1992, 1994),
- the afforestation registry and statistics of the Ministry of Environment and Energy,
- the "Agricultural Statistics of Greece" of the Hellenic Statistical Authority (EL.STAT., annual census),
- the "Distribution of the Country's Area by Basic Categories of Land Use" of the Hellenic Statistical Authority (EL.STAT., decennial survey),
- the "Land Use Change Database" of the Ministry of Environment and Energy, which comprises annual acts of land use change since 1990,
- the "Forest Management Plans Database", of the Ministry of Environment and Energy.
- the Corine Land Cover Database, of the European Environment Agency (years 1990, 2000, 2006, 2012 & 2018)
- the ILOTS of the Greek Payment Authority of Common Agricultural Policy Aid Schemes (OPEKEPE) since 2009
- the Forest Maps of the Ministry of Environment and Energy (Years 1945 & 2015)
- the area affected by wildfires from the European Forest Information System (EFFIS) since 2008

In the following ***Table 6.6*** all the above-mentioned data sources are classified, while their content and the land use category for which these data have been used are presented.

Table 6.6 The classification of the data sources and how they are used for the representation of land areas

Data source	Content	Land use category	Geographically explicit
The first National Forest Inventory (1st NFI) prepared by the General Secretariat of Forests and Natural Environment	Forest land area, Grassland area	Forest land, Grassland	
The afforestation registry and statistics of the Ministry of Environment and Energy	Afforestated/reforestated area	Land converted to Forest land	
The "Agricultural Statistics of Greece" of the Hellenic Statistical Authority	Cropland area, Cropland converted to Grassland area	Cropland, Cropland converted to Grassland	
The "Distribution of the Country's Area by Basic Categories of Land Use" of the Hellenic Statistical Authority	Area per land use category	Forest land, Cropland, Grassland, Wetlands, Settlements, Other land	

Data source	Content	Land use category	Geographically explicit
The "Forest Management Plans Database", of the Ministry of Environment and Energy since 1975	Managed forest land area	Forest land remaining forest land	
The "Land Use Change Database" of the Ministry of Environment and Energy, which comprise acts of land use change since 1990	Area of land use categories converted to other land uses	Forest land/Grassland converted to other land uses, Other land converted to Settlements	
The Corine Land Cover database	Area of croplands converted to settlements	Cropland converted to Settlements	x
The OPEKEPE LPIS	Area of croplands, different crop types	Cropland	x
The NDVI analysis using Sentinel satellite imagery for 2020-2021, 2021-2022, 2022 - 2023	Area of land use changes	Forest, Grassland, Cropland, Wetland, Settlements, Other land	x
The ratified forest maps for 95% of the country	Area of cropland, forest-forest land and grassland	Forest, Grassland, Cropland	x
The areas of wildfires (EFFIS)	Area of burnt area	Forest, Grassland	x

All available data from the data sources listed above have been used for the land-use change matrices development.

More information on the use of these datasets and the land-use definitions used in the classification of areas is given under the corresponding category in the following chapters.

For the development of the land use, land-use change matrices the results of the two "Distribution of the Country's Area by Basic Categories of Land Use" projects of the Hellenic Statistical Authority have been used. Both of the projects constitute complete, in terms of land use coverage, cadastre surveys providing the necessary information on the distribution of land areas per each land use category. The 1st survey provides for the country land use area distribution for the year 1990, while the second one provides data for the year 2000.

In this context, the total country area has been chosen as the one estimated in the latter survey. For the purposes of the land use, land-use change matrices development, the area difference of the total country area between the two surveys has been classified under Grassland category in 1990. The forest land area between the two years where the survey conducted was estimated using linear interpolation, while for the period after 2000 using linear extrapolation. For the cropland area, annual estimates provided by the Hellenic Statistical Authority have been used. For the annual land areas of croplands converted to settlements the Corine Land Cover (CLC) database has been utilised. More specifically, for the periods 1990-2000, and 2000-onwards, the CLC datasets of changes 1990-2000, and 2000-2006 have been used, respectively.

Land use changes since reference year 2021 have been identified using geographically explicit data, remote sensing and ILOTS OPEKEPE geodata. Remote sensing analysis was based on the Normalized Difference Vegetation Index (NDVI), using satellite imagery (Sentinel-2 MSI data:

MultiSpectral Instrument, Level-2A) and the Google Earth Engine platform. While ILOTS are available for the entire country since 2009, the classification applied for the land use categories mostly refers to their eligibility for funding under the Financial Aid Schemes of the CAP. Therefore, this information was used mostly for croplands and grasslands.

The NDVI is a dimensionless index that describes the difference between visible and near-infrared reflectance of vegetation cover and can be used to estimate the density of green on an area of land (Weier and Herring, 2000). The analysis process included the production of 2 normalized difference vegetation index (NDVI) raster thematic layers, one for the reporting year and one for the previous one. Applying map algebra in Google Earth Engine to these two layers a new layer of mosaic data was produced which provided the differences in the NDVI values between the two years. Classification schemes proposed in literature were applied to identify the range of values that represented land use change.

Finally, the areas were cross-checked with other available sources (Orthophotos 2015, Google earth, forest maps) to select actual land use change and not errors resulting from the satellite imagery data or processing. The result of the NDVI index in many cases could not be used directly, so additional non-automated processing was needed. Nevertheless, the checks showed that this method satisfactorily detected significant land use changes. The geographic data used for the checks included:

1. the areas affected by wildfire from the European Forest Fire Information System EFFIS (http://beyond-eocenter.eu/index.php/web-services/effis)

2. the dataset *Tree cover loss 2001-2021* from the Global Forest Watch platform (https://www.globalforestwatch.org/).

Late spring and summer (01/05 – 31/08) were selected as the observation period to identify land use changes using the NDVI in order to exclude errors related to cloud/ snow cover and annual vegetation variation in broadleaves during winter. Geodata from EFFIS allowed the exclusion of areas affected by wildfires that could be mistaken for land use change.

The NDVI was used to identify and map land use changes between 2022 – 2023 for most of the land use change categories. Data from OPEKEPE were used to identify Grassland converted to Cropland, Cropland converted to Grassland and Other Land converted to Settlements. For the other land use categories, linear extrapolation was applied for this submission.

6.3 Forest land (CRT Source Category 4A)

6.3.1 Category description

Carbon stock changes in five carbon pools (aboveground biomass, belowground biomass, dead wood, litter and soil organic matter) and emissions of non-CO_2 gases from Forest Land remaining Forest Land and Land converted to Forest Land have been assessed and reported under this category.

Carbon stocks increased during the period 1990 – 2023 due to biomass increment in Forest Land remaining Forest Land. Non-CO_2 greenhouse gases released to the atmosphere during biomass burning. Estimates of emissions / removals in this category are presented in ***Table 6.7.*** No associated emissions and removals are reported for Land converted to Forest Land, since only natural forest expansion occurs in Greece.

The sink capacity of Forest Land has increased from approximately -1.25 Mt CO_2 eq in 1990 to -2.13 Mt CO_2 eq in 2023. This rising trend is attributed mainly to the reduction in fellings, increase of stand age and rehabilitation of coppices to high forest due to sustainable forest management.

Table 6.7 Net GHG emissions / removals (in kt) from Forest Land by subcategory and gas for the period 1990 – 2023

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Forest land remaining forest land											
CO_2	-1310.03	-1361.31	-1744.18	-1800.06	-1508.52	-1678.98	-1669.73	-1390.99	-1569.93	-1550.96	-1512.13
CH_4	1.88	0.71	2.06	2.15	1.88	1.23	0.51	1.49	4.66	0.30	5.73
N_2O	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.03	0.00	0.04
Land converted to forest land											
CO_2	NE,NO	NE,NO	NE,NO	NE,NO	-9.36	-23.55	-30.29	-48.26	-54.00	-88.58	-51.07
CH_4	NO	NO	NO	NO	0.00	0.01	0.00	0.02	0.06	0.00	0.10
N_2O	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	-1254.00	-1340.07	-1682.69	-1735.98	-1461.81	-1665.65	-1684.78	-1394.41	-1483.23	-1630.56	-1389.12

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Forest land remaining forest land											
CO_2	-1793.01	-1800.13	-1831.39	-1832.50	-2214.57	-2196.32	-2030.15	-2070.85	-2062.30	-2067.40	-2070.08
CH_4	0.61	0.06	0.09	0.23	0.19	0.57	7.51	1.17	1.27	0.54	0.23
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.01	0.00	0.00
Land converted to forest land											
CO_2	-71.94	-103.41	-88.67	-89.77	-118.07	-116.34	5.98	-87.71	-101.86	-136.11	-124.44
CH_4	0.01	0.00	0.00	0.01	0.00	0.02	0.20	0.03	0.03	0.01	0.01
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	-1846.53	-1901.79	-1917.42	-1915.35	-2326.80	-2295.21	-1794.15	-2122.75	-2125.16	-2186.97	-2187.44

IPCC categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Forest land remaining forest land												
CO_2	-2067.34	-2077.63	-2086.78	-2089.99	-2106.74	-2107.87	-2108.54	-2209.21	-2213.68	-2108.82	-2146.69	-1680.35
CH_4	0.85	0.07	0.04	0.17	0.48	0.21	0.16	0.83	0.33	5.08	1.99	16.89
N_2O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03	0.01	0.08
Land converted to forest land												
CO_2	-118.92	-139.18	-139.93	-107.45	-107.04	-49.33	-44.36	-60.42	-48.32	-44.22	-40.96	-19.98
CH_4	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.12
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	-2160.11	-2214.82	-2225.41	-2201.37	-2199.15	-2150.70	-2148.13	-2244.83	-2252.07	-2001.27	-2129.23	-1201.49

NO: Not Occurring; NA: Not Applicable; NE: Not Estimated

6.3.2 Methodology

The definition of forest land used in this inventory is the definition used to report under the Kyoto Protocol:

- minimum area of 0.3 hectares,
- tree crown cover larger than 25 per cent,
- minimum height of 2 metres, or the potential to achieve it.

Carbon stock changes and greenhouse gas emissions and removals associated with changes in biomass and soil organic carbon are estimated and reported only for managed forests. Hence, this inventory estimates carbon stock changes and emissions of non-CO_2 gases from forests that have been managed with a forest management plan. The associated area equals approximately 1275.5 kha.

6.3.2.1 Forest land remaining forest land

The section "Forest land remaining Forest land (FF)" describes the estimation of changes in carbon stock in the five carbon pools, as well as emissions of non-CO_2 gases from these pools, in forest lands which have been forest lands for at least the past 20 years. The results of estimations are reported in the appropriate subdivision of the land use category (i.e. managed forest land). The summary equation, which estimates the annual emissions or removals from FF with respect to changes in carbon pools, is given in the following equation:

$$\Delta C_{FF} = (\Delta C_{FF_{LB}} + \Delta C_{FF_{DOM}} + \Delta C_{FF_{Soils}})$$

where, ΔC_{FF} is the annual change in carbon stocks from forest land remaining forest land, t C yr^{-1}, $\Delta C_{FF_{LB}}$ is the annual change in carbon stocks in living biomass (includes above and belowground

biomass) in forest land remaining forest land, t C yr^{-1}, $\Delta C_{FF_{DOM}}$ is the annual change in carbon stocks in dead organic matter (includes dead wood and litter) in forest land remaining forest land, t C yr^{-1} and $\Delta C_{FF_{Soils}}$ is the annual change in carbon stocks in soils in forest land remaining forest land, t C yr^{-1}.

Change in carbon stocks in living biomass

The methodology applied is consistent with the carbon stock change method described in the 2006 GL AFOLU (equation 2.8). According to this method, estimations of carbon stock changes are based on the difference in biomass stocks in a forest area at two points in time. The annual change in the carbon stocks in a forest area is the difference between the carbon stocks at time t_2 and time t_1, divided by the number of years between the inventories:

$$\Delta C_{FF_{LB}} = (C_{t_2} - C_{t_1}) / (t_2 - t_1)$$

where, $\Delta C_{FF_{LB}}$ is the annual change in carbon stocks in living biomass (includes above and belowground biomass) in forest land remaining forest land, t C yr^{-1}, C_{t_2} is the total carbon in biomass calculated at time t_2, t C, C_{t_1} is the total carbon in biomass calculated at time t_1, t C.

The total carbon in biomass is calculated according to the equation:

$$C_{t_i} = [V_{t_i} \cdot D \cdot BEF] \cdot (1+R) \cdot CF$$

Where, C_{t_i} is the total carbon in biomass calculated at time t_i (t C), V_{t_i} is the merchantable volume at time t_i (m^3 ha^{-1}), D is the basic wood density of merchantable volume (t dry matter m^{-3}), BEF is the biomass expansion factor for conversion of merchantable volume to aboveground tree volume (dimensionless), R is the root-shoot ratio (dimensionless), and, CF is the carbon fraction of dry matter (t C (t d.m.)$^{-1}$).

CO_2 emissions and removals from managed forests are calculated according to the equation above, comparing the carbon stocks in forest biomass that is estimated by the successive forest management plans (FMP). Annual change in carbon stocks in every studied forest during the period of two inventories is estimated by linear interpolation, while for the period before the first and after the last inventory is estimated by linear extrapolation. For these estimations 1,725 forest management plans (FMP) have been considered, from which only 405 were used that are currently in effect.

The information from the FMPs includes the area of forest land, wood volume and increment. Broadleaves account for 51% of the wood volume in managed Forest Land, whereas conifers and mixed forests represent 33% and 16% respectively. Official disaggregated data on forests and forest areas are being collected by the on-going 2nd national inventory, which began in 2023. A central database containing the field measurements, vegetation maps, volume and increment data is expected to become available at the end of the project, in 2025. Moreover, a permanent monitoring network of sampling plots has been established, which will be used to assess the impact of climate change on forests with future remeasurements.

The merchantable volume, V, and the area covered by each forest are obtained from the FMPs. The disaggregation of the area by forest species is based on the classification of the 1st NFI (43% Conifers, 57% Broadleaves). The IPCC default factor (CF = 0.47) was used for the conversion of dry matter to carbon throughout the inventory. Default factors for root-shoot ratio R were selected for each forest species from the 2006 IPCC Guidelines (vol. 4, table 4.4). The below-ground biomass to above-ground biomass ratio values used were selected taking into account the forest type, ecological zone and above-ground biomass stock levels of the forest, as shown in ***Table 6.8***.

Table 6.8 Ratio of below-ground biomass to above-ground biomass (R)

Forest type	Above-ground biomass	R ([tonne root d.m. (tonne shoot d.m.)-1]
Conifers	< 50 tonnes ha^{-1}	0.4
	50 - 150 tonnes ha^{-1}	0.29
	> 150 tonnes ha^{-1}	0.2
Broadleaves	< 75 tonnes ha^{-1}	0.46
	75 - 150 tonnes ha^{-1}	0.23
	> 150 tonnes ha^{-1}	0.24
Mixed forest	< 50 tonnes ha^{-1}	0.3
	50 - 150 tonnes ha^{-1}	0.255
	> 150 tonnes ha^{-1}	0.2

Source: Table 4.4, 2006 IPCC Guidelines, Temperate ecological zone

The 2006 GL AFOLU suggest the use of Biomass Expansion Factors for the conversion of merchantable volume to aboveground tree biomass. Since, national expansion factors have not been developed in Greece, factors developed for Mediterranean species under similar climatic and ecological conditions, in the frame of the Ecological and Forest Inventory of Catalonia, were used instead. In this inventory, biomass expansion factors BEF (for the conversion of merchantable volume to aboveground tree volume) and the wood density D (for the conversion of tree volume to tree biomass) are combined in one factor BEFD that directly converts the merchantable volume to aboveground tree biomass.

Table 6.9 Biomass expansion factors BEFD used for biomass estimation

Conifers	BEFD
Abies sp.	0.61
Pinus halepensis	0.74
Pinus pinea	0.73
Pinus brutia	0.73
Pinus nigra – Other conifers	0.64
Pinus sylvestris	0.62

Picea abies	0.44
Cupressus sp.	0.55
Broadleaves	**BEFD**
Fagus sp.	0.81
Deciduous oaks– Other broadleaves	0.89
Quercus ilex – Evergreen oaks	1.28
Castanea sativa	0.75
Betula pendula	0.73
Alnus sp. – Populus sp.	0.62
Ulmus sp. – Platanus sp.	0.90
Fraxinus sp.	0.83

Source: Centro de Investigacion Ecologica y Aplicaciones Forestales (CREAF)

Following previous ERT's recommendation, Greece decided to proceed with a verification of the estimates of carbon stock changes in living biomass resulted from the use of the carbon stock change method as described previously. The Carbon Budget Model[5] (CBM) was used for that purpose and the whole work has been carried out in the framework of the technical assistance on Land Use, Land Use Change and Forestry reporting and accounting provided by the Joint Research Centre, European Commission, in the context of task 2b of the Administrative Arrangement No 071201/2011/611111/CLIMA.A2 (Analysis of and proposals for enhancing, monitoring, reporting and verification of land use, land use change and forestry in the EU-LULUCF MRV).

The CBM model is an inventory-based, yield-data driven model that simulates the stand-and landscape-level C dynamics of above- and belowground biomass, and dead organic matter (DOM) including soil (Kurz et al., 2009). It is compliant with the carbon estimation methods outlined in the guidelines of the Intergovernmental Panel on Climate Change. The model uses much of the same information that is required for forest management planning activities (e.g., forest inventory, growth and yield curves, natural and human-induced disturbance information, forest management schedule, and land-use change information), supplemented with information from national ecological parameter databases (Operational-Scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)/User's Guide).

In order the model to run, the necessary input data provided by Greece were used, which comprised the forest area under management, volume and increment data, a reference year, forest fire area data, and harvest amount data. In particular, the volume and increment data were derived from the same forest management plans used in the carbon stock change method.

The results of this analysis are presented in ***Figure 6.3*** below.

[5] http://www.nrcan.gc.ca/forests/climate-change/13107

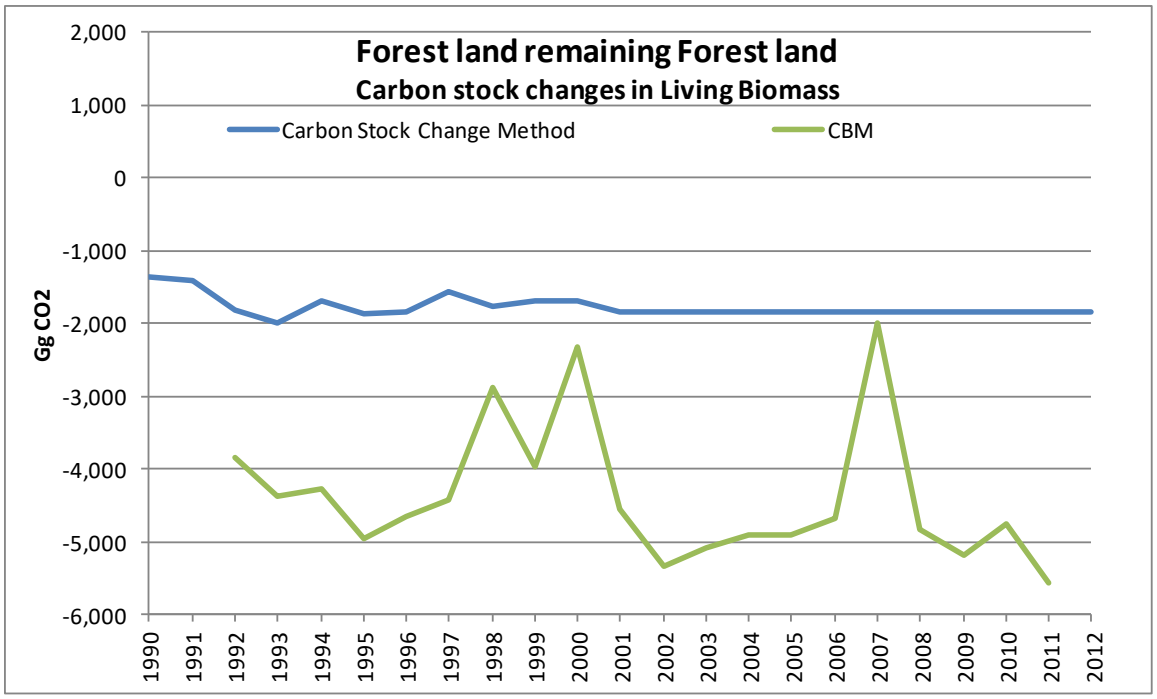


Figure 6.3 ***Comparison of the carbon stock changes in Living biomass in Forest land remaining Forest land, with the application of Carbon Stock Change Method and the CBM[6]***

As depicted in the figure above, the trend of the carbon stock changes in living biomass is almost the same between the two methods, during the period 1990 - 2012. Nevertheless, there is a difference in the sink magnitude with the carbon stock change method appearing to be the most conservative one. In addition, some remarkable peaks in the CBM results as illustrated in the graph need closer attention. These values refer to the years 1998, 2000, 2007 and are mainly attributed to the effects of forest fires. Those three years considered to be exceptional ones in the history of modern Greece, in terms of forest area burnt. On the other hand, the implication of the use of the carbon stock change method, is the "smoothing" of the net emissions/removals of CO_2 in Forest land remaining Forest land category, since these emissions are not depicted in the year an event (i.e. forest fire) occurs, but they are distributed over the period as determined by the two points in time the carbon stocks are measured.

Change in carbon stocks in dead organic matter

Changes in carbon stocks in two types of dead organic matter pools have to be considered: a) dead wood and b) litter. Until 2020 IPCC Guidelines were applied, which do not require estimation or reporting on dead wood or litter, on the assumption that the time average value of these pools will remain constant, with inputs to dead matter pools balanced by outputs. This Tier1 approach was followed for dead organic matter carbon stocks in all forest land and was considered as true-to-life

[6] The analysis was made during the Inventory submission for 2014.

since these lands do not experience significant changes in forest types or management regimes. Prescribed fires and post logging burning of harvest residues are not practiced in Greece.

The change in DOM carbon stocks in Forest Land remaining Forest Land is estimated using equation 2.18 of the 2006 IPCC Guidelines (Gain – Loss method) since the FMPs do not include any information on dead wood or litter to apply the Stock difference method as for living biomass.

$$\Delta CDOM = A \bullet [(DOMin - DOMout) \bullet CF]$$

Where, ΔCDOM is the annual change in carbon stocks in the dead wood/litter pool (tonnes C yr-1), A is the area of managed land (ha), DOMin is the average annual transfer of biomass into the dead wood/litter pool due to annual processes and disturbances (tonnes d.m. ha^{-1} yr^{-1}), DOMout is the average annual decay and disturbance carbon loss out of dead wood or litter pool, (tonnes d.m. ha^{-1} yr^{-1}) and CF is the carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$, equal to 0.47.

DOM input for Greece includes the harvesting residues and annual mortality whereas DOM output the annual decay and carbon loss due to wildfires. Annual mortality and decay rates are considered constant, thus harvesting residues and losses from wildfires are the main drivers for the carbon stock change in this pool.

DOM input has been estimated based on the assumption that harvesting residues equal 1% of the harvested wood volumes based on empirical data and expert judgment. Biomass in burnt areas is assumed to have been completely lost, which is consistent with the approach followed for wildfires.

The results of this analysis have been included in the carbon stock change reported in CRT table 4.A for the entire timeseries (1990 – 2023).

Change in carbon stocks in soils

Two types of forest soil organic pools are considered under this category: a) the organic fraction of mineral forest soils, and b) organic soils. CO_2 emissions / removals from soils are associated with changes in the amount of organic carbon stored in soils. These changes are a function of the balance between inputs to soil of photosynthetically fixed carbon and losses of soil carbon via decomposition. In general, changes in forest type, management intensity and disturbance regime alter the carbon dynamics of forest soils. Under Tier 1, it is assumed that when forest remains forest the carbon stock in soil organic matter of mineral soils does not change, regardless of changes in forest management, forest types, and disturbance regimes, i.e. the carbon stock in mineral soil remains constant so long as the land remains forest. In Greece, forest type and management activities, such as silvicultural system, rotation length, harvest practices, site preparation activities do not change significantly over time, and therefore Tier 1 assumption can be used without introducing significant error in the calculations.

Changes in carbon stocks of organic soils are associated with drainage and management perturbations of these soils. In Greece, areas of organic soils covered by forest are negligible, remain in a natural state and therefore greenhouse gas emissions/removals have not been considered.

Wildfires - Non CO_2 greenhouse gas emissions

The carbon stock change method used to estimate emissions and removals from managed forests – and forests under art. 3.4 activity Forest Management – encompasses the loss of carbon in areas affected by wildfires. For this reason, no extra emissions of CO_2 from biomass as a result of wildfires are reported. The implication of the use of this method on the inventory is the normalisation of the net emissions/ removals of CO_2 from the LULUCF sector, since these emissions are not reported at the year of disturbance – that resulted in high annual fluctuation of emissions – rather than they are distributed over the period between the successive management plans.

However, the biomass burnt annually in managed forests had to be estimated, in order to estimate and report the non-CO_2 GHG emissions. According to IPCC Guidelines, CH_4 and CO emissions from wildfires were estimated as ratios to carbon released during burning ($L_{disturbance}$), and N_2O and NO_x emissions as ratios to total nitrogen released. Nitrogen content was calculated based on the nitrogen-carbon ratio (N/C was taken as 0.01).

$$CH_4 \text{ emissions} = L_{disturbance} \cdot 0.012 \cdot 16/12$$

$$CO \text{ emissions} = L_{disturbance} \cdot 0.06 \cdot 28/12$$

$$N_2O \text{ emissions} = L_{disturbance} \cdot (N/C \text{ ratio}) \cdot 0.007 \cdot 44/28$$

$$NO_x \text{ emissions} = L_{disturbance} \cdot (N/C \text{ ratio}) \cdot 0.121 \cdot 46/14$$

The IPCC default values for trace gas emission ratios were used, whereas the factors 16/12, 28/12, 44/28 and 46/14 were used to convert emissions to full molecular weights.

The annual carbon loss in living biomass from wildfires was estimated according to equation 2.14:

$$L_{disturbance} = \sum_i A_{disturbance\,i} \cdot Bw_i \cdot CF \bullet (1+R) \bullet fd$$

where, $L_{disturbance}$ is the annual decrease in carbon stocks due to biomass oxidation to the atmosphere (t C yr^{-1}), $A_{disturbance\,i}$ is the forest areas affected by wildfires, by forest type (i = 21) (ha yr^{-1}), Bw_i is the average biomass stock of forest areas, by forest type (t d.m. ha^{-1}), and CF is the carbon fraction of dry matter (t C (t d.m.)$^{-1}$), R is the ratio of below-ground biomass to above-ground biomass (t d.m. bg biomass (t d.m. ag biomass)$^{-1}$), fd is the fraction of biomass lost in disturbance.

It was assumed that the forest biomass in the area affected by wildfire was completely destroyed, i.e. there was no living biomass left in the area. Data on area affected by wildfires were obtained from the statistics of the Ministry of Environment and Energy, and the Fire Service disaggregated by two general categories; forests and grasslands. A flammability indicator for 21 forest types was developed, based on national statistics of areas burnt stratified by forest type during the period 1990 – 1996, in order to draw disaggregated activity data. Since data on burnt area of managed forests are not available, a weighted average is used, based on the total area burnt in each prefecture and the percentage of forests managed in this area. The fraction of biomass transferred to dead organic matter varies with the vegetation type (diameter of fuel). Two general values were assumed; fBL = 0.55 for forests and fBL = 0.28 for scrublands. The set of parameters used to estimate carbon loss in living biomass from wildfires are listed in ***Table 6.10***.

Table 6.10 Parameters used for the estimation of carbon loss in living biomass from wildfires

Species/ Vegetation type		Bwtotal (t dm/ha)	fBL dimensionless	*fd (1- fBL)* dimensionless	CF t C/t dm
Forest	*Pinus nigra*	56.91	0.55	0.45	0.47
	Pinus silvestris	110.92	0.55	0.45	0.47
	Pinus leucodermis	225.69	0.55	0.45	0.47
	Pinus halepensis	36.95	0.55	0.45	0.47
	Pinus brutia	36.95	0.55	0.45	0.47
	Pinus pinea	36.95	0.55	0.45	0.47
	Abies spp.	112.56	0.55	0.45	0.47
	Picea abies	287.02	0.55	0.45	0.47
	Cupressus sempervirens	51.74	0.55	0.45	0.47
	Castanea sativa	96.92	0.55	0.45	0.47
	Fagus spp.	155.69	0.55	0.45	0.47
	Betula pendula	155.69	0.55	0.45	0.47
	Quercus spp.	44.75	0.55	0.45	0.47
	Quercus ilex	44.75	0.55	0.45	0.47
	Deciduous broadleaves	60.66	0.55	0.45	0.47
Shrubland	Evergreen broadleaves	8	0.28	0.72	0.47
	Quercus cocciferae	8	0.28	0.72	0.47
Grassland	Grassland	2.2	0	1	0.47

BW is the average biomass stock of forest areas, by forest type (t d.m. ha-1), CF is the carbon fraction of dry matter (t C (t d.m.)-1), R is the ratio of below-ground biomass to aboveground biomass (t d.m. bg biomass (t d.m. ag biomass)-1), fd is the fraction of biomass lost in disturbance (1-fBL) and fBL is the Fraction of biomass left to decay in Forest.

The average biomass stock of each forest type was calculated from the average volume of growing stock given in the 1st NFI and the average biomass stock in the understorey vegetation, with the following equation:

$$Bw = V \cdot BCEFs$$

$$Bw_{understorey}$$

where, V is the average volume of growing stock, overbark (m^3 ha^{-1}), BCEFs is the biomass conversion and expansion factor for converting volumes of growing stock to total aboveground biomass, $Bw_{understorey}$ is the average biomass stock of understorey vegetation (t d.m. ha^{-1}).

The average biomass stock of understorey vegetation was acquired from a study reviewing relevant articles and the data of the 1st NFI (Kokkinidis, 1989). Appropriate IPCC default factors for biomass conversion and expansion factors, and the ratio of below-ground biomass to above-ground biomass were selected from Table 4.5, and Table 4.4 of the 2006 GL AFOLU, respectively. Finally, due to the methodology applied for estimating greenhouse gas emission from biomass burning in cropland converted to forest land, the respective proportion of emissions was subtracted from that reported under forest land remaining forest land category.

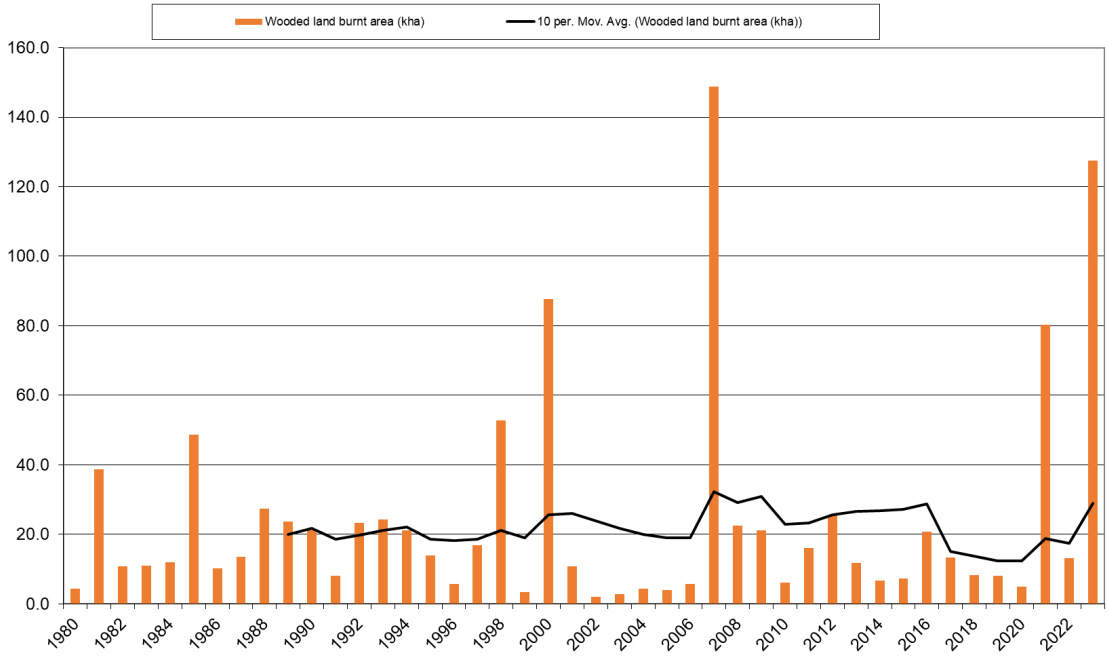


Figure 6.4 Areas of Forest Land burnt since 1980

In the current inventory CO_2 and non-CO_2 greenhouse gas emissions resulted from dead organic matter pool (dead wood and litter) subject to wildfires are reported. For those estimations, the same methodology described above has been followed, along with litter and dead wood stock values prior to wildfire presented in ***Table 6.14***, and ***Table 6.15***. In the case of dead organic matter subject to wildfires it was assumed a complete oxidation, the factor (fBLi) was taken equal to "0".

N_2O and NO_x are also produced in soils as a by-product of nitrification and denitrification. Emissions are stimulated by N fertilisation of forests and drainage of wet forest soils. Such emissions have not been considered since these activities do not occur in forest lands of the country.

6.3.2.2 Land converted to Forest Land

This section describes the estimates of carbon stock changes and greenhouse gas emissions and removals from lands converted to forest land during the last 20 years. Managed land is converted to forest land by afforestation, either by natural or artificial regeneration. In this inventory changes in carbon stocks in croplands converted to forest land since 1994, under the EEC Regulations 2080/92 and 1257/99, have been estimated. Grasslands converted to forestland constitute natural forest expansion and therefore there are no associated emissions by sources and removals by sinks. This kind of conversion is not directly human induced, but rather occurs under natural drivers. Following previous ERT's recommendation, Greece reports the area of grassland converted to forest land, according to the methodology described in section 6.3. The estimation of carbon change was based on the summary equation.

$$\Delta C_{LF} = (\Delta C_{LF_{LB}} + \Delta C_{LF_{DOM}} + \Delta C_{LF_{Soils}})$$

where, ΔC_{LF} is the annual change in carbon stocks in land converted to forest land, t C yr^{-1}, $\Delta C_{LF_{LB}}$ is the annual change in carbon stocks in living biomass (includes above and belowground biomass) in land converted to forest land, t C yr^{-1}, $\Delta C_{LF_{DOM}}$ is the annual change in carbon stocks in dead organic matter (includes dead wood and litter) in land converted to forest land, t C yr^{-1} and $\Delta C_{LF_{Soils}}$ is the annual change in carbon stocks in soils in land converted to forest land, t C yr^{-1}.

Change in carbon stocks in living biomass

As already mentioned, in that section only changes in carbon stocks in croplands converted to forest land have been estimated and reported. These lands have been converted to forest land by planting in the context of the EEC Regulations. The carbon stock change in living biomass has been calculated taking into account the increase and the decrease of carbon stocks related to the areas converted to forest land, following the equation below:

$$\Delta C_{LF_{LB}} = (\Delta C_{LF_{GROWTH}} - \Delta C_{LF_{LOSS}})$$

where, $\Delta C_{LF_{LB}}$ is the annual change in carbon stocks in living biomass, t C yr^{-1}, $\Delta C_{LF_{GROWTH}}$ is the annual increase in carbon stocks in living biomass due to biomass growth in land converted to forest land, t C yr^{-1}, and $\Delta C_{LF_{LOSS}}$ is the annual decrease in carbon stocks due to biomass loss in land converted to forest land, t C yr^{-1}.

In the absence of country specific data with regard to annual losses in carbon stocks in living biomass in those areas and based on the work done in the context of the EU "Project on Assistance to MS with KP Reporting", it was decided emission factors from a neighbouring country to be used instead. In particular, an average value each year for the period 1990 - 2020 from the most updated implied emission factors (IEFs) of four Italian regions, namely Abruzzo, Molise, Basilicata and Puglia, was applied. Those specific four regions were selected based on the most similar climatic and ecological conditions to Greece. Moreover, these IEFs explicitly include afforested and reforested land, as mentioned in the Italian NIR (p.327 NIR 2019). They are thus considered appropriate for estimating the CSCs in living biomass for AR.

For the estimation of the annual increase in carbon stocks in living biomass, an average IEF was used for the above-ground and below-ground biomass separately, each year. Similarly, decreases in carbon stocks in living biomass were estimated applying an average IEF from the four Italian regions and the above-ground and below-ground biomass were treated separately each year, according to the equation below:

$$\Delta C_{LF_{GROWTH/LOSS}} = (IEF_{AGavg} + IEF_{BGavg}) \cdot A$$

where, $\Delta C_{LF_{GROWTH/LOSS}}$ is the annual increase/decrease in carbon stocks in living biomass, t C yr^{-1}, IEF_{AGavg} is the average IEF each year for increase/decrease in above-ground biomass from the four Italian regions, t C ha^{-1}, IEF_{BGavg} is the average IEF each year for increase/decrease in below-ground biomass from the four Italian regions, t C ha^{-1}, and A is the area converted to forest land, ha. Data on area afforested were obtained from the statistics of the Ministry of Environment and Energy. In ***Table 6.11*** the IEFs used for the estimation of carbon stock changes in living biomass in land converted to forest land are presented.

Table 6.11 Average IEFs from four Italian regions (Abruzzo, Molise, Basilicata, Puglia) that were used for the estimation of carbon stock changes in living biomass in land converted to forest land

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
IEF for increase in living biomass (Gg kha^{-1})															
Above-ground	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.96	1.96	1.96	1.96	1.96
Below-ground	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
IEF for decrease in living biomass (Gg kha^{-1})															
Above-ground	1.14	1.05	1.09	1.29	1.09	1.00	1.17	1.19	1.15	0.98	1.37	1.27	1.01	1.23	1.28
Below-ground	0.23	0.22	0.22	0.25	0.22	0.20	0.23	0.24	0.23	0.19	0.28	0.25	0.20	0.25	0.26

IPCC categories	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
IEF for increase in living biomass (Gg kha^{-1})															
Above-ground	1.96	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.94	1.94	1.94	1.93	1.93	1.93	1.93
Below-ground	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37
IEF for decrease in living biomass (Gg kha^{-1})															
Above-ground	1.12	1.15	1.91	1.35	1.26	1.04	1.13	1.16	1.03	0.95	1.10	0.99	1.39	1.40	0.98

Below-ground	0.22	0.23	0.36	0.27	0.25	0.20	0.22	0.22	0.21	0.19	0.22	0.20	0.27	0.27	0.19

IPCC categories	2020	2021	2022	2023
IEF for increase in living biomass (Gg kha^{-1})				
Above-ground	1.93	1.93	1.93	1.93
Below-ground	0.37	0.37	0.37	0.37
IEF for decrease in living biomass (Gg kha^{-1})				
Above-ground	1.02	1.02	1.02	1.02
Below-ground	0.20	0.20	0.20	0.20

No changes in carbon stocks in living biomass are reported for grassland that is converted to forest land through natural expansion, since this conversion is not directly human induced.

Change in carbon stocks in dead organic matter

Changes in carbon stocks in dead organic matter were estimated using the methodology described above for Forest Land remaining Forest Land. The implied carbon stock change factors for net carbon stock change in dead wood and litter per area were applied from the Forest Land remaining Forest Land category. It is noted that the conversion of cropland to forest land only refers to afforestation projects under EEC Regulations 2080/92 and 1257/99, with a duration of 20 years and only minimum human activities until the final logging. Therefore, the likely level of emissions was estimated using the average value of 0.065 kt CO2 eq. and maximum value 0.10 kt CO2 eq. to ensure that they are well below 0.05 per cent of the national total GHG emissions, and do not exceed 500 kt CO2 eq. The results of this analysis show that this category is insignificant in terms of emissions and removals and is thus reported as “NE” in the CRT tables, according to decision 24/CP.19 paragraph 37.

No changes in carbon stocks in dead organic matter are reported for grassland that is converted to forest land through natural expansion, since this conversion is not directly human induced.

Change in carbon stocks in soils

Carbon stock change in soils for afforested land has been reported using a Tier 2 methodology, applied also for Cropland remaining Cropland (perennial woody crops). The approach followed is described in detail in Par.6.4.2.1).

No changes in carbon stocks in soils are reported for grassland that is converted to forest land through natural expansion, since this conversion is not directly human induced.

Wildfires - Non CO_2 greenhouse gas emissions

Grassland is naturally converted to unmanaged forest land, therefore no loss of carbon or non-CO_2 GHG emissions due to wildfires is reported.

6.3.3 Uncertainty and time series consistency

Uncertainty estimates for the whole inventory period (1990-2023) have been assessed following Approach 1 of the 2006 GL AFOLU. Input uncertainties related to activity data and emission factors have been assessed on the basis of information provided mainly from the 2006 GL AFOLU and country specific information.

In ***Table 6.12*** below, the associated uncertainties with the above-mentioned parameters for forest land remaining forest land and land converted to forest land are presented.

Table 6.12 Parameter uncertainties values

	%	Source
Area	10	Expert judgment based on country specific information
BEFD	47	2006 GL AFOLU
R	77	2006 GL AFOLU
Growing stock volume	30	2006 GL AFOLU
Carbon fraction of dry matter	2	2006 GL AFOLU
Above ground net biomass growth	88	2006 GL AFOLU
Average dead wood stock of forest areas	4.6	GHG Italian NIR 2016
Average litter stock of forest areas	72	2006 GL AFOLU

The uncertainty assessment has been performed using equations 3.1, and 3.2 as contained in volume 1 of the 2006 GL AFOLU following the complete estimation process implemented in the inventory for estimating GHG emissions/removals.

The overall uncertainty for forest land remaining forest land is equal to 18%, 57%, 57% for CO_2, CH_4, N_2O emissions respectively, while for land converted to forest land associated uncertainties equal to 76%, 62%, 62% for CO_2, CH_4, N_2O emissions respectively. A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

6.4 Cropland (CRT Source Category 4B)

6.4.1 Category description

Carbon stock changes in Cropland remaining Cropland and in Land converted to Cropland are estimated and reported in this category. Carbon stock changes in living biomass and soil in Cropland remaining Cropland were caused by changes in management practices and crop type. Emissions of CH_4 and N_2O from these lands were estimated as part of *Agriculture*. The net CO_2 emissions / removals from each subcategory are presented in ***Table 6.13.***

Table 6.13 Net GHG emissions / removals (in kt) from Cropland by subcategory for the period 1990 – 2023

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Cropland remaining cropland											
CO_2	-818.55	-884.59	-854.14	-1110.29	-1051.01	-1143.72	-448.84	-1112.99	-958.49	-1173.15	-1099.86
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to cropland											
CO_2	52.28	58.46	12.39	12.61	12.35	12.47	12.47	12.34	12.39	12.48	75.26
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total (kt CO_2 eq)	-765.81	-825.21	-840.82	-1096.75	-1037.73	-1130.31	-435.43	-1099.72	-945.17	-1159.74	-1023.10

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Cropland remaining cropland											
CO_2	-877.27	-976.33	-655.99	-741.06	-888.81	-888.42	34.77	-980.81	-839.01	-645.37	-926.10
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to cropland											
CO_2	88.93	27.92	27.98	28.02	27.84	27.88	27.99	27.87	27.92	22.09	15.78
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total (kt CO_2 eq)	-786.24	-946.30	-625.91	-710.93	-858.86	-858.43	64.87	-950.83	-808.99	-621.63	-909.13

IPCC categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cropland remaining cropland											
CO_2	-980.82	10.67	422.42	-323.47	-790.08	-658.37	-1010.42	-1334.85	-1223.45	-1328.55	-1298.92
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

IPCC categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to cropland											
CO_2	15.73	15.78	16.07	15.76	15.93	15.94	16.01	16.28	16.56	17.18	19.93
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	-963.90	27.64	439.68	-306.51	-772.95	-641.24	-993.21	-1317.37	-1205.68	-1310.14	-1277.73

IPCC categories	2023
Cropland remaining cropland	
CO_2	-1216.18
CH_4	NO
N_2O	NO
Land converted to cropland	
CO_2	16.74
CH_4	NO
N_2O	0.00
Total (kt CO_2 eq)	-1198.17

NO: Not Occurring; NA: Not Applicable; NE: Not Estimated

According to the Agricultural Statistics of the Hellenic Statistical Authority of Greece, during the last 40 years tree crops have almost doubled in area, mainly against cereal crops. This considerable change in crops cultivated has resulted in the creation of a sink in the increasing biomass stocks where carbon is accumulating. The magnitude of this sink is about -0.01 to -1.49 Mt CO_2 eq yr^{-1} during the period 1990 – 2023 (with the exception of the years 2013 and 2014 in which the category acts as a source). Carbon stock changes in mineral soils are the result of changes in practices or management through time. Hence, since there weren't different set of data demonstrating subsequent changes in management during the period under investigation, carbon stock changes have been estimated to be zero. Cultivation of organic soils resulted in net emissions of 244 kt CO_2 yr^{-1} annually during the same period.

6.4.2 Methodology

Cropland includes all annual and perennial crops as well as temporary fallow land and has been categorized as Perennial woody crops and Non-woody crops.

6.4.2.1 Cropland remaining cropland

The Paragraph "Cropland Remaining Cropland (CC)" describes the estimation of changes in carbon stock in living biomass and soil pools in croplands which have been croplands for at least the past 20 years. The following summary equation was used:

$$\Delta C_{CC} = \Delta C_{CC_{LB}} + \Delta C_{CC_{DOM}} + \Delta C_{CC_{Soils}}$$

where, ΔC_{CC} is the annual change in carbon stocks in cropland remaining cropland, t C yr^{-1}, $\Delta C_{CC_{LB}}$ is the annual change in carbon stocks in living biomass in cropland remaining cropland, t C yr^{-1}, $\Delta C_{CC_{DOM}}$ is the annual change in carbon stocks in dead organic matter in cropland remaining cropland, t C $yr^{-1}$and $\Delta C_{CC_{Soils}}$ is the annual change in carbon stocks in soils in cropland remaining cropland, t C yr^{-1}.

Change in carbon stocks in living biomass

i) Perennial woody crops

A Tier 2 methodology was used to estimate carbon stock changes in living biomass for perennial woody crops, with country-specific values for areas and carbon accumulation and loss rates. Perennial woody crops (e.g. tree crops) accumulate biomass for a finite period until they are removed through harvest or reach a steady state where there is no net accumulation of carbon in biomass because growth rates have slowed and incremental gains from growth are offset by losses from natural mortality or pruning. After this period, perennial woody crops are replaced by new ones and carbon stored in biomass is released to the atmosphere through burning (on-site or off-site) or decomposition. These crops constitute therefore a significant carbon pool, but when management practices or crop type do not change, it is assumed that removals from biomass increment are balanced by emissions from harvest, and thus in a long term, they are neither a sink nor a source of carbon.

Changes in carbon stocks in living biomass were only estimated when new plantations of such perennial woody crops, i.e. tree crops and vineyards for the case of Greece, were established or eradicated (changed to a different crop type).

$$\Delta C_{CC_{LB}} = \Delta C_{CC_G} - \Delta C_{CC_L}$$

where, $\Delta C_{CC_{LB}}$ is the annual change in carbon stocks in living biomass in cropland remaining cropland and changes crop type, t C yr^{-1}, ΔC_{CC_G} is the annual increase in carbon stocks due to biomass growth in new plantations, t C yr^{-1} and ΔC_{CC_L} is the annual decrease in carbon stocks due to biomass loss in eradicated crops, t C yr^{-1}.

It was assumed that these plantations accumulate biomass linearly until they reach maturity, assumed to be at half the replacement cycle (***Figure 6.5***). During maturity biomass increases are offset by losses from pruning - in order the tree to be retained to the desired form - and natural

mortality, and hence changes in living biomass are assumed to be zero. The annual growth rate (G_W), during the growth period, is derived thus by dividing biomass stock at maturity (B_M) by the time from crop establishment to maturity reach ($\lambda/2$). The annual increase in carbon stocks due to biomass growth in new plantations was calculated as:

$$\Delta C_{CC_G} = \sum_i \sum_{j=k-(\lambda i/2)-1}^{k} A_{planted_{ij}} \cdot G_{W_i} \cdot CF\,,\ G_{W,i} = {B_{M,i}}/{(\lambda_i/2)}$$

where, $A_{planted_{ij}}$ is the area where new plantations were established, by crop type (i = 15), ha yr^{-1}, G_{W_i} is the growth rate in new plantations, by crop type, t d.m. ha^{-1} yr^{-1}, CF is the carbon fraction of dry matter, t C (t d.m.) $^{-1}$, k is the inventory year, B_{M_i} is the average biomass stock at maturity, by crop type, d.m. ha^{-1} and λ_i is the average replacement cycle, by crop type, yr.

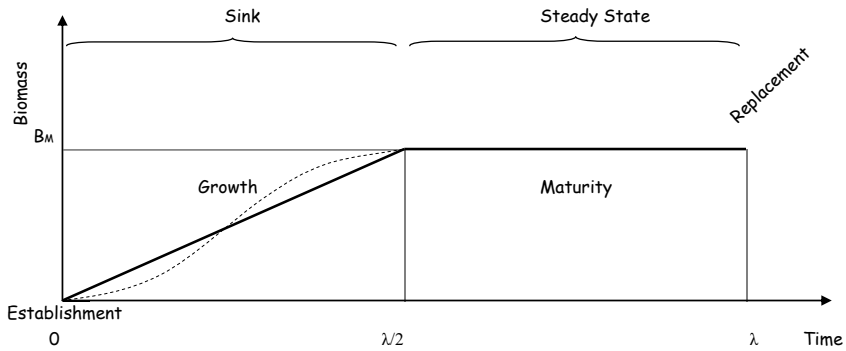


Figure 6.5 Assumed biomass accumulation in new plantations

The default annual loss rate is equal to biomass stocks at replacement (B_M), which are assumed to be removed entirely in the year of removal. The annual decrease in carbon stocks due to biomass loss from eradication (ΔC_{CC_L}) was estimate as:

$$\Delta C_{CC_L} = \sum_i A_{eradicated_i} \cdot B_{M\,i}$$

where, $A_{eradicated_i}$ is the area of crop eradicated, by crop type (i = 15), ha yr^{-1} and B_{M_i} is the average biomass stock at maturity / replacement, by crop type, t d.m. ha^{-1}.

Data on areas planted and eradicated were obtained from the "Agricultural Statistics of Greece" of the Hellenic Statistical Authority, disaggregated by 15 crop types (14 tree crops and vineyards). Data on the factors B_M and λ for these crops were obtained from the Ministry of Rural Development and Food and expert judgment and are presented in ***Table 6.14***.

According to the 2006 GL AFOLU, changes in dead organic matter have not been estimated since it is assumed that the dead wood and litter stocks either are not present or are at equilibrium.

Table 6.14 ***Average biomass stock at maturity and replacement cycle for the different crop types***

Crop Type	B_M (tonnes d.m. ha^{-1})	λ (yr)
Vineyards	12	26
Citrus trees (orange. lemon. mandarin. biter orange. citron. bergamot trees)	54	30
Apple trees	54	26
Pear trees	48	26
Peach trees	48	26
Apricot trees	60	30
Cherry trees	60	40
Other orchards[7]	60	40
Almond trees	60	40
Walnut trees	60	50
Pistachio trees	42	30
Fig trees for dried figs	42	30
Other nuts dried fruit[8]	54	50
Other trees[9]	54	50
Olive trees	71	50

ii) Non-woody crops

For non-woody crops, increase in biomass stocks in a single year was assumed equal to biomass losses from harvest and mortality in that same year - thus there was no net accumulation of biomass carbon stocks.

Change in carbon stocks in soils

A Tier 2 methodology was used for the estimation of carbon stock changes in soil, with country specific data for areas and soil organic carbon reference values and IPCC default stock change factors. The annual change in carbon stocks in soils in cropland remaining cropland ($\Delta C_{CC_{Soils}}$, t C yr^{-1}) was estimated as the difference between the annual emissions from cultivated organic soils ($\Delta C_{CC_{Organic}}$, t C yr^{-1}) and the annual change in organic carbon stocks in mineral soils ($\Delta C_{CC_{Mineral}}$, t C yr^{-1}).

$$\Delta C_{CC_{Soils}} = \Delta C_{CC_{Mineral}} - \Delta C_{CC_{Organic}}$$

Mineral soils

[7] Includes Sour cherry, Quince, Prunellas, Fresh fig, Plum, Chinese gooseberries, Pomegranate trees.
[8] Includes Chestnut, Hazelnut trees.
[9] Includes Carob, Avocado, Mastic, Medlar, Banana, other kinds trees.

The estimation method for mineral soils is based on changes in soil C stocks over a finite period following changes in management that impact soil C, and consequently changes in concentration of soil carbon is only driven by the change in practices or management, as shown in the equation 2.25 of the 2006 GL AFOLU:

$$\Delta C_{CC_{Mineral}} = [\ \sum_{p,i}(SOC_0) - \sum_{,p,i}(SOC_{(0-T)})\ ] \bullet A_{,p,i} / D$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, SOC_0 is the soil organic carbon stock in the inventory year, t C ha^{-1}, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, t C ha^{-1}, D is the time dependence of stock change factors which is the default time period for transition between equilibrium SOC values , 20 years, A is the land area of each parcel, ha, p represents the land parcel, *i* represents the set of cropland types or crop type categories, SOC_{REF} is the reference soil organic carbon stock, t C ha^{-1}, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

Reference soil organic C stocks (SOC_{REF}) were estimated based on national data available from the Global Soil Organic Carbon Map (FAO,2019)[10], climate zones from the Köppen-Geiger climate classification (Kottek et al, 2006; Kottek and Rubel, 2010; Rubel et al, 2017) and land use polygons of natural vegetation from ratified Forest maps (land categorized as Forest which includes forest land and shrubs). The analysis results are presented in ***Table 6.15***. Due to the wide range of SOC stock values in each climate zone the mean was not considered reliable and thus the weighted average value was used instead.

Table 6.15 Mean and weighted average of soil organic carbon stock under natural vegetation per climate zone

Climate Zone	Area (kha)	SOC Min (t C/ha)	SOC Max (t C/ha)	SOC Mean (t C/ha)	SOC Weighted Avg (t C/ha)
Arid	52.67	26	95	44.94	38.77
Warm temperate, dry	5,357.66	1	194	80.63	49.19
Warm temperate, humid	174.57	1	160	71.88	46.90
Continental, dry	19.48	17	156	65.14	53.80
Continental, humid	23.40	31	170	58.51	50.26
Total	5,627.79	1	194	70.86	49.05

Since the climate in most of the country (94%) is warm temperate, dry the value 49.19 t C/ha was used as the SOC_{REF}. The 2006 GL AFOLU default values $F_{LU,}$ F_{MG} and F_I from Table 5.5 were used for boreal/ temperate temperature regime and dry moisture regime, as shown in ***Table 6.16***.

[10] The development of the GSOC map for Greece was carried out with the contribution of the Hellenic Agricultural Organization "DIMITRA", Institute of Soil and Water Resources utilizing national data and FAO common methodology for all participating countries.

Table 6.16 Stock change factors applied per crop type and management practices

Land use category	F_{LU}
Longterm cultivated	0.80
Paddy rice	1.10
Perennial/tree crop	1.00
Set aside (<20 years)	0.93

For longtem cultivated land			
Tillage	F_{MG}	C Input	F_I
Full	1	Low	0.95
Reduced	1.02	Medium	1.00
No-till	1.10	High without manure	1.04

Crop types and changes in management practices were estimated using Corine Land Cover (CLC) data for years 1990, 2012 and 2018. For land set aside OPEKEPE data were used since the CLC classification does not include a distinct category. Tillage extent was estimated based on EUROSTAT data which indicated that 82% of arable land was under full tillage, 13% under reduced tillage and 5% under no tillage. These percentages were applied across the time-series. Input category was determined following 2006 GL AFOLU classification. The classification applied is shown in ***Table 6.17***.

Table 6.17 Crop classification per IPCC land use category, tillage method and C input category

LU category	CLC code	Crop type	Tillage	Input category
Longterm cultivated	211	Non-irrigated arable land	Reduced	Medium C input
	211	Non-irrigated arable land	Full	Low C input
	212	Permanently irrigated land	Reduced	High C input
	231	Pasture	No-till	Low C input
	241	Annual crops associated with permanent crops	No-till	High C input
	242	Complex cultivation patterns	Reduced	Medium C input
	243	Land principally occupied by agriculture with significant areas of natural vegetation	No-till	High C input
Rice	213	Rice fields	NA	NA
Perennial crops	221	Vines	NA	NA
	222	Tree crops	NA	NA
	223	Olive groves	NA	NA
Set aside	-	Land set aside	No-till	Low C input

Soil organic carbon stock was estimated for the years 1990, 2010 and 2021 and the change over the time-series was estimated using interpolation, as shown in ***Table 6.18***.

Table 6.18 Carbon stock change in SOC of mineral soils in Cropland remaining Cropland for the period 1990 -2023

Year	Area (kha)			Carbon Stock Change (kt C)		
	Total area	Perennial woody crops	Non Woody crops	Total CSC	Perennial woody crops	Non Woody crops
1990	3935.19	1067.56	2867.63	NO	NO	NO
1991	3932.85	1075.16	2857.70	4.19	1.30	2.89

Year	Area (kha)			Carbon Stock Change (kt C)		
	Total area	Perennial woody crops	Non Woody crops	Total CSC	Perennial woody crops	Non Woody crops
1992	3929.85	1077.11	2852.74	8.39	2.60	5.79
1993	3908.14	1081.36	2826.77	12.58	3.90	8.68
1994	3906.33	1089.27	2817.06	16.62	6.19	10.43
1995	3903.53	1093.83	2809.69	20.79	7.74	13.05
1996	3898.92	1100.59	2798.34	24.97	9.29	15.68
1997	3892.72	1116.19	2776.53	29.19	10.84	18.35
1998	3878.92	1121.34	2757.58	33.34	12.38	20.96
1999	3874.22	1142.61	2731.60	37.57	13.93	23.64
2000	3870.25	1152.76	2717.49	41.75	15.48	26.27
2001	3866.53	1155.14	2711.39	45.92	17.03	28.90
2002	3854.31	1160.51	2693.80	50.11	18.58	31.53
2003	3840.18	1163.19	2677.00	54.36	20.12	34.23
2004	3776.38	1164.10	2612.29	58.58	21.67	36.90
2005	3750.24	1170.21	2580.03	62.79	23.22	39.57
2006	3739.40	1172.31	2567.08	66.99	24.77	42.22
2007	3718.44	1160.63	2557.82	71.15	26.32	44.84
2008	3710.24	1171.44	2538.80	75.35	27.86	47.49
2009	3701.93	1173.04	2528.89	79.55	29.41	50.13
2010	3689.64	1171.08	2518.56	83.73	30.96	52.77
2011	3588.72	1172.26	2416.46	95.52	36.40	59.12
2012	3581.57	1172.70	2408.88	107.25	41.85	65.40
2013	3532.91	1158.51	2374.41	118.85	47.29	71.56
2014	3340.45	1138.75	2201.70	130.48	52.73	77.74
2015	3295.27	1136.59	2158.68	142.26	58.18	84.08
2016	3264.02	1136.31	2127.71	153.87	63.62	90.26
2017	3135.63	1127.08	2008.55	165.23	69.06	96.17
2018	3096.67	1134.07	1962.60	176.88	74.50	102.37
2019	3044.63	1148.50	1896.13	188.45	79.95	108.50
2020	3021.05	1148.71	1872.34	199.84	85.39	114.45
2021	3006.65	1168.19	1838.46	211.14	90.48	120.66
2022	2985.65	1172.73	1812.93	222.84	96.28	126.57
2023	2953.45	1166.53	1786.92	220.53	95.77	124.76

Organic Soils

Unlike the situation of mineral soils, where carbon fluxes are driven by changes in soil carbon stocks followed by changes in management, emissions from organic soils were estimated as net annual flux caused by cultivation and continuous exhaustion of organic matter. The annual loss of carbon from organic soils was estimated using a Tier1 method based on the equation 2.26 of the 2006 GL AFOLU.

$$\Delta C_{CC_{Organic}} = A_{Organic} \cdot EF$$

where, $\Delta C_{CC_{Organic}}$ represents CO_2 emissions from cultivated organic soils in cropland remaining cropland, t C yr^{-1}, $A_{Organic}$ is the land area of cultivated organic soils, ha and EF is the emission factor for cultivated organic soils, t C $ha^{-1}yr^{-1}$.

All cultivated organic soils are found under warm temperate climate, hence one climate type was considered when choosing the emission factor (EF = 10 t C $ha^{-1}yr^{-1}$, Table 5.6, 2006 GL AFOLU). Area of cultivated organic soils was obtained from a study of the Soil Science Institute of Athens (SSIA, 2001).

6.4.2.2 Land converted to Cropland

Changes in biomass, dead organic matter, and soil carbon stocks associated with Forest land and Grassland conversion to Cropland are addressed in this category. CO_2 emissions and removals in land use conversion to cropland result from the removal of existing and replacement with different vegetation. For the area of forest lands and grasslands converted to cropland, direct estimates of spatially disaggregated areas converted annually for each initial forest or grassland type were used. These data were provided by the local Forest Service for each land unit converted.

Change in carbon stocks in living biomass

The methodology used to estimate C stock changes in biomass in forest land and grassland converted to cropland follows the 2006 GL AFOLU approach as proposed by equations 2.15 and 2.16, where the carbon stock change is equal to the carbon stock change due to removal of biomass from the initial land use (i.e. carbon in biomass immediately after conversion minus the carbon in biomass prior to conversion), plus carbon stocks from biomass growth following conversion.

$$\Delta C_{LC_{LB}} = A_{Conversion} \cdot (L_{Conversion} + \Delta C_{Growth})$$

$$L_{Conversion} = C_{After} - C_{Before}$$

where, $\Delta C_{LC_{LB}}$ is the annual change in carbon stocks in living biomass in land converted to cropland, t C yr^{-1}, $A_{Conversion}$ is the annual area of land converted to cropland from some initial use, ha yr^{-1}, $L_{Conversion}$ is the carbon stock change per area for that type of conversion when land is converted to cropland, t C ha^{-1}, ΔC_{Growth} is the carbon stocks from one year of growth of cropland vegetation after conversion, t C ha^{-1}, C_{After} is the carbon stocks in biomass immediately after conversion to cropland, t C ha^{-1}, C_{Before} is the carbon stocks in biomass immediately before conversion to cropland, t C ha^{-1}. The average carbon stocks in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock Bw of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground biomass stocks were approximated using the root-shoot ratio. As a result of conversion, it is assumed that the dominant vegetation is removed entirely, thus C_{After} =0.

Change in carbon stocks in dead organic matter

For the estimation of carbon stock changes in dead organic matter in forest land converted to cropland, the methodology applied is consistent with the 2006 GL AFOLU , according to which two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), t C yr^{-1}, ΔC_{DW} is the change in carbon stocks in dead wood, t C yr^{-1}, ΔC_{LT} is the change in carbon stocks in litter, t C yr^{-1}.

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{DOM} = (C_n - C_o) \cdot A_{on}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr^{-1}, C_o is the dead wood/litter stock under the old land use category, t C ha^{-1}, C_n is the dead wood/litter stock under the new land use category, t C ha^{-1}, A_{on} is the area converted from forest land to cropland, ha.

It is assumed that all carbon contained in dead wood and litter is removed during conversion and that there is no dead wood or litter that remains or accumulates in land converted to cropland. Dead wood and litter stocks following conversion are assumed to be equal to zero.

For the estimation of litter stocks prior to conversion, the data collected within the European project BioSoil in Greece, were used. Under the BioSoil project, 4 Level II plots from representative forest ecosystems in Greece have been surveyed in 2007. The results of the measurements and analyses performed were obtained from the MEEN and are presented in ***Table 6.19***.

Table 6.19 Average litter carbon stocks of the four Level II plots in Greece, under the Biosoil project

Soil Layer	Plot 1 Maquis (t C ha^{-1})	Plot 2 Oak (t C ha^{-1})	Plot 3 Beech (t C ha^{-1})	Plot 4 Fir (t C ha^{-1})
L	7.10	5.01	5.17	4.96

Since information about the dead wood stocks in Greece was not available, data obtained from a neighbouring country were used instead. Consequently, for the estimation of the dead wood carbon stocks prior to conversion, dead wood coefficients from Italy were applied. Those coefficients were estimated on the basis of data collected in the framework of the Italian forest inventory[11] per Italian region and per inventory typology. A selection of the coefficients estimated for the Italian regions, for the different inventory typologies, was carried out, in order to detect only those that are more suitable to Greek climatic conditions and vegetation types, respectively. The coefficients used to estimate the carbon stock changes in the deadwood pool are reported in the ***Table 6.20***.

Table 6.20 Dead mass in the different Italian regions per inventory typology

Dead mass dry matter (Mg ha^{-1})	Lazio	Molise	Campania	Puglia	Basilicata	Calabria	Sicilia
silver fir	0.000	1.550	0.000	0.000	6.840	1.430	0.000
mountain pines	1.180	0.585	1.375	0.825	0.755	2.065	0.845
mediterranean pines	3.410	0.000	0.720	0.910	0.850	4.260	0.550
other conifers	9.140	0.000	0.810	2.850	5.560	6.420	4.060
european beech	1.680	2.330	1.240	2.600	1.100	2.350	0.940
other oaks	0.750	2.350	0.940	0.890	0.300	1.050	1.400
other broadleaves	1.200	2.270	1.020	1.210	0.410	1.080	1.940
sweet chestnut	7.980	8.960	4.010	1.030	5.470	7.800	7.620
hornbeams	1.700	2.560	1.020	0.870	2.110	0.210	1.490
evergreen oaks	1.410	0.000	1.880	0.300	0.350	1.040	0.930
other broadleaves coppices	1.820	0.000	1.070	0.600	0.000	0.000	0.110
riparian forest	3.240	4.420	4.250	0.000	0.920	2.580	3.200
shrublands	0.210	0.000	0.000	0.940	0.410	1.260	1.530

Each prefecture in Greece was assigned to one of the Italian regions described above based on its regional climatic and vegetation cover characteristics, using expert judgment.

For the conversion of dry matter to carbon the IPCC factor (CF = 0.47) was used.

DOM in grasslands is assumed to be zero and, thus, no carbon stock changes in DOM have been estimated.

Change in carbon stocks in soils

A Tier 1 methodology was used for the estimation of carbon stock changes in soils in forest land and grassland converted to cropland, with country specific data and IPCC default coefficients. The annual change in carbon stocks in soils in land converted to cropland ($\Delta C_{LC_{Soils}}$, t C yr^{-1}) was

[11] http://www.sian.it/inventarioforestale/jsp/home_en.jsp; Further information related to the methodology applied to deduce the deadwood coefficients may be found in the paper *L. Di Cosmo et all, 2013*.

estimated as the difference between the annual emissions from cultivated organic soils converted to cropland ($\Delta C_{LCOrganic}$, t C yr^{-1}) and the annual change in organic carbon stocks in mineral soils in land converted to cropland ($\Delta C_{LCMineral}$, t C yr^{-1}).

$$\Delta C_{LCSoils} = \Delta C_{LCMineral} - \Delta C_{LCOrganic}$$

In Greece, areas of organic soils covered by forest are negligible, remain in a natural state and therefore greenhouse gas emissions/removals have not been considered.

Mineral soils

The Tier 1 method applied for the estimation of carbon stock changes in mineral soils in forest land and grassland converted to cropland is based on the 2006 GL AFOLU using the equation 2.25:

$$\Delta C_{LCMineral} = [\,(SOC_0 - SOC_{(0-T)}) \cdot A] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{CCMineral}$ is the annual change in carbon stocks in mineral soils, t C yr^{-1}, SOC_0 is the soil organic carbon stock in the inventory year, t C ha^{-1}, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, t C ha^{-1}, T is the inventory time period, yr, A is the land area of each parcel, ha, SOC_{REF} is the reference soil organic carbon stock, t C ha^{-1}, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The 20 years inventory period was used (T = 20). The initial (pre-conversion) soil C stocks were determined assuming that the $F_{LU,}$ F_{MG}, F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks. The current soil C stocks (SOC_0) on land converted to cropland were estimated from the same reference soil C stocks together with representative stock change factors. According to the climatic classification (by Thornwaite) of Greece, about 80% of croplands are found on dry warm temperate climate and the rest 20% on moist warm temperate (Carras, 1973). Moreover, since land area data disaggregated by climatic type were not available, representative weighted average land use factor, management factor and input factor from Table 5.5 of the 2006 GL AFOLU were used, namely F_{LU} = 0.78, F_{MG} = 1.03, F_I = 1.00. For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece. The Ministry of Agriculture coordinated the project which lasted for approximately 20 years (1979-1998), and 2,260 plots were surveyed (the L layer was not sampled). The results are available in four different vegetation zones in Greece, and are presented in ***Table 6.21***, along with the representative plant species. In the cases where grassland converted to croplands the SOC_{REF} = 72.3 t C ha^{-1} value was used.

Table 6.21 Average carbon stocks in forest soils per vegetation zone in Greece

	Mediterranean zone (0 – 500 m)	Sub-Mediterranean zone (500 – 1000 m)	Mountainous zone (1000 – 1700 m)	Pseudoalpine zone (1700 – 2500 m)
Plant species	Evergreen broadleaf & Mediterranean Pine	Deciduous oak	Fir, Pine, Beech	Herbaceous vegetation
Average forest soil carbon stocks (t C ha^{-1})	72.3	80.3	116.0	111.0

6.4.3 Uncertainty and time series consistency

Uncertainty estimates for the whole inventory period (1990-2023) have been assessed following Approach 1 of the 2006 GL AFOLU. Input uncertainties related to activity data and emission factors have been assessed on the basis of information provided mainly from the 2006 GL AFOLU and country specific information.

In ***Table 6.22*** below, the associated uncertainties with the above-mentioned parameters for cropland remaining cropland and land converted to cropland are presented.

Table 6.22 Parameter uncertainties values

	%	Source
Area	10	Expert judgment based on country specific information
EF for organic soils cultivation	90	2006 GL AFOLU
R	77	2006 GL AFOLU
Forest land/Grassland above ground biomass	56	2006 GL AFOLU
Growth rate	28	Expert judgment based on country specific information
Carbon fraction of dry matter	2	2006 GL AFOLU
Soil organic carbon	18	FAO GSOC map
Average dead wood stock of forest areas	5	GHG Italy NIR 2016
Average litter stock of forest areas	72	2006 GL AFOLU

The uncertainty assessment has been performed using equations 3.1, and 3.2 as contained in volume 1 of the 2006 GL AFOLU following the complete estimation process implemented in the inventory for estimating GHG emissions/removals.

The overall uncertainty for cropland land remaining cropland is equal to 109%, while for land converted to cropland associated uncertainties equal to 27%, for CO_2 emissions. A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

Methodological changes made in 2014 to the collection of data resulted in an increase in the area under cropland remaining cropland. Prior to 2014, unofficial data was collected voluntarily from farmers. The Hellenic Statistical Authority, in cooperation with the Ministry of Agricultural Development and Foods, redesigned the Annual Agricultural Research in 2014. An electronic questionnaire was designed and implemented, which was filled in by certified Statistical

Correspondents. Moreover, changes in the crops that were included in each category applied in 2013 led to inconsistencies that were corrected in the 2025 NIR submission, based on information of the Ministry of Agriculture that were cross-checked with OPEKEPE and ELSTAT data. The methodology for data collection currently being implemented has not been modified since 2014. However, additional action is required to calculate areas accurately, which is part of the planned improvements.

6.5 Grassland (CRT Source Category 4C)

6.5.1 Category description

Grassland includes rangeland and pasture with vegetation that falls below the threshold of forest definition and are not expected to exceed it without human intervention. CO_2 emissions from Grassland remaining Grassland and from Land converted to Grassland are reported under this category, as well as non-CO_2 emissions from wildfires (***Table 6.23***).

Table 6.23 Net GHG emissions / removals (in kt) from Grassland for the period 1990 – 2023

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Grassland remaining grassland											
CO_2	0.19	0.20	0.04	0.50	0.03	0.03	0.03	0.10	0.04	0.03	0.04
CH_4	0.63	0.53	1.61	1.13	1.18	0.50	0.54	0.81	1.59	0.18	2.48
N_2O	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.02
Land converted to grassland											
CO_2	0.03	0.00	1.45	54.37	-44.53	-42.79	-48.29	-47.83	-64.91	-88.48	-109.15
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	18.95	16.06	49.52	88.83	-9.10	-27.51	-31.83	-23.22	-17.12	-82.68	-34.62

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Grassland remaining grassland											
CO_2	0.02	0.18	0.06	0.02	0.01	0.28	0.21	0.03	0.37	0.03	0.07
CH_4	0.50	0.09	0.13	0.31	0.23	0.25	5.14	0.54	0.54	0.10	0.48
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Land converted to grassland											
CO_2	-109.15	-91.37	-106.89	-59.54	-287.24	-375.69	-379.00	-444.81	-458.25	-464.72	-333.61
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	-93.80	-87.99	-102.66	-49.88	-280.07	-367.41	-225.14	-428.21	-441.38	-461.20	-318.93

IPCC categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Grassland remaining grassland											
CO_2	0.38	0.00	0.15	0.05	0.17	0.87	0.51	0.27	0.18	0.38	0.00
CH_4	0.87	0.57	0.33	0.26	0.78	0.52	0.62	2.28	0.42	0.40	0.23
N_2O	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.00
Land converted to grassland											
CO_2	-773.97	-670.40	-512.77	-1250.68	-1393.00	-1277.06	-1712.32	-1770.89	-1944.31	-2011.78	-2040.82
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	-747.15	-653.15	-502.54	-1242.75	-1369.66	-1260.52	-1693.35	-1702.73	-1931.70	-1999.44	-2034.03

IPCC categories	2023
Grassland remaining grassland	
CO_2	0.29
CH_4	2.05
N_2O	0.01
Land converted to grassland	
CO_2	-2,071.29
CH_4	NO
N_2O	0.00
Total (kt CO_2 eq)	-2009.88

NO: Not Occurring; NA: Not Applicable; NE: Not Estimated

6.5.2 Methodology

6.5.2.1 Grassland remaining Grassland

The living biomass pool in grassland includes above and belowground carbon stocks in woody and herbaceous vegetation. Grasslands in Greece are extensively managed without significant management improvements (e.g. species changes, irrigation, fertilisation) and management practices applied are generally static. Hence, the Tier 1 assumption that is no change in biomass stocks was followed for the majority of these lands, except some cases where vegetation clearing took place and woody vegetation was substituted by annual vegetation. In these lands, CO_2 emissions result from the removal of existing and replacement with different vegetation. The amount of C stock change in living biomass was estimated by multiplying the area of intervention by the difference in carbon stocks between biomass in the land prior to intervention (C_{Before}) and after the intervention (C_{After}). The equation used to estimate annual changes in carbon stocks in living biomass is:

$$\Delta C_{GG_{LB}} = A \bullet (C_{After} - C_{Before})$$

where, $\Delta C_{GG_{LB}}$ is the annual change in carbon stocks in living biomass, t C yr^{-1}, A is the area of intervention, ha yr^{-1}, C_{After} is the carbon stocks in living biomass immediately after intervention, t C ha^{-1}, C_{Before} is the carbon stocks in living biomass immediately before intervention, t C ha^{-1}. Actual areas of intervention have been provided by the local Forest Service disaggregated by vegetation type.

The methods used to estimate emissions from wildfires in grasslands are those described in Forest land section, all carbon in the aboveground biomass is assumed to be released to the atmosphere upon disturbance, and no transfer to dead organic pool is considered, f_{BL} = 0. However, CO_2 released is assumed to be removed by photosynthesis of vegetation regrowing during the subsequent year and therefore only emissions of non-CO_2 gases are reported. For these estimations two grassland types were considered; one with herbaceous vegetation and average biomass stock of

2.2 t d.m. ha^{-1} and one with woody vegetation (shrubland) and average biomass stock of 8 t dm . ha^{-1} (Kokkinidis, 1989). Data on area of grasslands burnt were obtained from the statistics of the Ministry of Environment and Energy (GDFFE, annual statistics), and the Fire Service.

According to the 2006 GL AFOLU, it is assumed that the dead wood and litter stocks are at equilibrium, thus no carbon stock changes for these pools have been reported. Concerning the carbon pool in mineral soils, all area was characterised as nominal managed both in the inventory year and 20 years ago, and hence according to the equation 2.25, $F_{LU}= F_{MG} = F_I = 1$ and $\Delta C_{GG_{Mineral}} = 0$, i.e. the annual change in carbon stocks in mineral soils was zero. Changes in carbon stocks of organic soils are associated with drainage and other management perturbations of these soils. In Greece, areas of organic soils under the grassland classification are negligible, remain in a natural state and therefore greenhouse gas emissions/removals have not been considered. Non-CO_2 emissions from other sources (e.g. CH_4 emissions from grazing livestock on grassland) were estimated and reported in the *Agriculture* sector.

The methods used to estimate emissions from wildfires in grasslands are the same as those described in Forest land section, based on equation 2.14 of the 2006 IPCC Guidelines.

6.5.2.2 Land converted to Grassland

Changes in biomass and soil C stocks associated with Forest land and Cropland conversion to Grassland, as well as changes in dead organic matter in Forest land converted to Grassland are addressed in this category.

Table 6.24 Net CO_2 emissions / removals (kt CO_2) from Land converted to Grassland by subcategory for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Land converted to Grassland	0.03	0.00	1.45	54.70	-44.19	-42.35	-47.82	-47.36	-64.44	-88.00	-108.68
Biomass	0.01	NO	3.13	91.23	8.70	8.63	10.59	30.45	32.30	20.51	NO
Dead Organic matter	0.01	NO	0.04	11.61	0.08	3.95	1.50	0.02	0.05	0.16	NO
Soils	0.00	0.00	-1.72	-48.47	-53.31	-55.36	-60.38	-78.30	-97.26	-109.15	-109.15

IPCC category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Land converted to Grassland	-108.68	-90.90	-106.41	-59.05	-286.75	-375.20	-378.52	-444.33	-457.75	-464.22	-333.11
Biomass	0.00	43.17	63.75	269.82	102.93	35.04	76.98	27.03	27.87	53.80	449.98
Dead Organic matter	NO	0.02	0.27	0.20	NO	0.04	0.06	0.07	1.00	0.10	NO
Soils	-109.15	-134.56	-170.90	-329.56	-390.17	-410.76	-456.04	-471.90	-487.12	-518.62	-783.60

IPCC category	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Grassland	-773.97	-670.23	-512.60	-1250.62	-1392.96	-1277.02	-1712.32	-1770.89	-1944.31	-2011.78	-2040.82
Biomass	18.95	184.41	820.19	195.12	115.80	519.51	157.59	209.81	86.19	45.49	39.70

Dead Organic matter	0.05	NO	NO	NO	0.09	0.13	0.18	0.64	0.73	0.34	0.16
Soils	-792.97	-854.81	-1332.96	-1445.80	-1508.89	-1796.70	-1870.09	-1981.34	-2031.23	-2057.60	-2080.68

IPCC category	2023
Land converted to Grassland	-2071.29
Biomass	24.05
Dead Organic matter	NO
Soils	-2095.33

Change in carbon stocks in living biomass

Since Greek law allows the land use change of Forest land only in cases of national interest, there is only a very small area where such deforestation occur (e.g. construction of high-tension lines). The carbon emissions and removals in land use conversion to grassland result from the removal of existing and replacement with different vegetation, and from the establishment of vegetation in cropland areas when these are abandoned. The methodology used to estimate C stock changes on these lands follows the 2006 GL AFOLU equations 2.15 and 2.16, where the carbon stock change is equal to the carbon stock change due to removal of biomass from the initial land use (i.e. carbon in biomass immediately after conversion minus the carbon in biomass prior to conversion), plus carbon stocks from biomass growth following conversion. As a result of conversion, it is assumed that the dominant vegetation is removed entirely, after which the area is taken over by grassland.

$$\Delta C_{LG_{LB}} = A_{Conversion} \cdot (L_{Conversion} + \Delta C_{Growth})$$

$$L_{Conversion} = C_{After} - C_{Before}$$

where, $\Delta C_{LG_{LB}}$ is the annual change in carbon stocks in living biomass in land converted to grassland, t C yr^{-1}, $A_{Conversion}$ is the annual area of land converted to grassland from some initial use, ha yr^{-1}, $L_{Conversion}$ is the carbon stock change per area for that type of conversion when land is converted to grassland, t C ha^{-1}, ΔC_{Growth} is the carbon stocks from one year of growth of grassland vegetation after conversion, t C ha^{-1}, C_{After} is the carbon stocks in biomass immediately after conversion to grassland, t C ha^{-1}, C_{Before} is the carbon stocks in biomass immediately before conversion to grassland, t C ha^{-1}.

For the area of forest land converted to grassland, direct estimates of spatially disaggregated areas converted annually for each initial forest type and each final grassland type, were used. These data were provided by the local Forest Service for each land unit converted until 2020. In the current submission geographically explicit data have been used to estimate the relevant areas, as described in ***Section 6.2***.

The average carbon stock in biomass immediately before conversion C_{Before} was obtained from the average biomass stock B_W of each forest type, as calculated in the category Forest land remaining Forest land. Carbon stocks in biomass immediately after conversion are assumed to be zero (C_{After} = 0). For these estimations two grassland types were considered; one with herbaceous vegetation and average biomass stock of 2.2 t d.m. ha^{-1} and one with woody vegetation (shrubland) and average aboveground biomass stock of 8 t dm ha^{-1} (Kokkinidis, 1989). Belowground biomass stocks were approximated using the default root-shoot ratio.

Croplands that have been abandoned and taken over by grassland were also considered in this section. When such conversions occurred in Greece it has been assumed, using expert judgment, that these lands were mostly annual crops. Carbon stocks in biomass immediately after conversion assumed to be zero (C_{After} = 0), while for the carbon stocks before conversion the default value for annual crops (C_{Before} = 5 t C ha^{-1}) from table 5.9 of the 2006 GL AFOLU was used. Finally, for the carbon stocks from one year of growth of grassland vegetation after conversion, a weighted average value from Table 6.4 of the 2006 GL AFOLU (0.8*6.1+0.2*13.5=7.6) was used, according to the climatic classification (by Thornwaite) of Greece.

Change in carbon stocks in dead organic matter

For the estimation of carbon stock changes in dead organic matter in forest land converted to grassland, the methodology applied is consistent with the 2006 GL AFOLU , according to which two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), t C yr^{-1}, ΔC_{DW} is the change in carbon stocks in dead wood, t C yr^{-1}, ΔC_{LT} is the change in carbon stocks in litter, t C yr^{-1}.

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{DOM} = (C_n - C_o) \cdot A_{on}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr^{-1}, C_o is the dead wood/litter stock under the old land use category, t C ha^{-1}, C_n is the dead wood/litter stock under the new land use category, t C ha^{-1}, A_{on} is the area converted from forest land to grassland, ha.

It is assumed that all carbon contained in dead wood and litter is removed during conversion and that there is no dead wood or litter that remains or accumulates in forest land converted to grassland. Dead wood and litter stocks following conversion are assumed to be equal to zero.

For the estimation of litter stocks prior to conversion, the data collected within the European project BioSoil in Greece (MEEN), were used (***Table 6.19***).

Since information about the dead wood stocks in Greece was not available, data obtained from a neighbouring country were used instead. Consequently, for the estimation of the dead wood carbon stocks prior to conversion the dead wood coefficients estimated on the basis of data collected in the framework of the Italian forest inventory per Italian region and per inventory typology were used instead (***Table 6.20***).

For the conversion of dry matter to carbon the IPCC factor (CF = 0.47) was used.

Change in carbon stocks in soils

A Tier1 methodology was used for the estimation of carbon stock changes in soils in forest land and cropland converted to grassland, with country specific data and IPCC default coefficients. The annual change in carbon stocks in soils in land converted to grassland ($\Delta C_{LG_{Soils}}$, t C yr^{-1}) was estimated as the difference between the annual emissions from organic soils converted to grassland ($\Delta C_{LG_{Organic}}$, t C yr^{-1}) and the annual change in carbon stocks in mineral soils in land converted to grassland ($\Delta C_{LG_{Mineral}}$, t C yr^{-1}).

$$\Delta C_{LG_{Soils}} = \Delta C_{LG_{Mineral}} - \Delta C_{LG_{Organic}}$$

Neither forestland nor cropland on organic soils have been converted to grassland, and therefore emissions from organic soils have not been considered.

Mineral soils

For the Tier 1 method the equation 2.25 of the 2006 GL AFOLU, was used:

$$\Delta C_{LG_{Mineral}} = [\,(SOC_0 - SOC_{(0-T)}) \cdot A] / T$$

$$SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LG_{Mineral}}$ is the annual change in carbon stocks in mineral soils, t C yr^{-1}, SOC_0 is the soil organic carbon stock in the inventory year, t C ha^{-1}, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, t C ha^{-1}, T is the inventory time period, yr, A is the land area of each parcel, ha, SOC_{REF} is the reference soil organic carbon stock, t C ha^{-1}, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The IPCC default inventory time period was used (T = 20). In the case of forest land conversion to grassland the initial (pre-conversion) soil C stocks were determined assuming that the F_{LU}, F_{MG}, F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks. The current soil C stocks (SOC_0) on land converted to grassland were estimated from the same reference soil C stocks together with the stock change factors that apply to severely degraded grassland (i.e. F_{LU} = 1.0, F_{MG} = 0.7, F_I = 1.0, Table 6.2 2006 GL AFOLU). For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece (***Table 6.21***).

In the case of cropland conversion to grassland the initial (pre-conversion) soil C stocks were determined using the same stock change factors as in section 6.5.2.2, namely F_{LU} = 0.78, F_{MG} = 1.03, F_I = 1.00. The current soil C stock $SOC_{(0)}$ was assumed equal to the reference (SOC_{REF}) soil C stocks, using the 72.3 t C ha^{-1} value from ***Table 6.21,*** applicable to Evergreen broadleaf & Mediterranean Pine.

6.5.3 Uncertainty and time series consistency

Uncertainty estimates for the whole inventory period (1990-2023) have been assessed following Approach 1 of the 2006 GL AFOLU. Input uncertainties related to activity data and emission factors have been assessed on the basis of information provided mainly from the 2006 GL AFOLU and country specific information.

In ***Table 6.25*** below, the associated uncertainties with the above-mentioned parameters for grassland remaining grassland and land converted to grassland are presented.

Table 6.25 Parameter uncertainties values

	%	Source
Area	15	Expert judgment based on country specific information
R	77	2006 GL AFOLU
Forest land above ground biomass	56	2006 GL AFOLU
Cropland carbon stock	75	2006 GL AFOLU
Carbon fraction of dry matter	2	2006 GL AFOLU
Grassland biomass stock after conversion from other land use	75	2006 GL AFOLU
Average dead wood stock of forest areas	5	GHG Italy NIR 2016
Average litter stock of forest areas	72	2006 GL AFOLU

The uncertainty assessment has been performed using equations 3.1, and 3.2 as contained in volume 1 of the 2006 GL AFOLU following the complete estimation process implemented in the inventory for estimating GHG emissions/removals.

The overall uncertainty for grassland remaining grassland is equal to 43%, 57%, 57% for CO_2, CH_4 and N_2O emissions, while for land converted to grassland associated uncertainties equal to 34%, for

CO_2 emissions. A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

6.6 Wetlands (CRT Source Category 4D)

6.6.1 Category description

Wetlands include land that is covered or saturated by water for all or the greatest part of the year (e.g. lakes, reservoirs, marshes), as well as riverbed (including torrent beds) and that does not fall into the forest land, cropland, grassland or settlements categories. In this category, carbon stock changes, as well as N_2O and CH_4 emissions associated with organic soils managed for peat extraction and flooded lands in the category Land converted to Wetlands have to be reported. The first activity is not considered since it does not occur in the country. Flooded lands are defined as water bodies regulated by human activities for energy production, irrigation, recreation, etc., and where substantial changes in water area due to water level regulation occur.

The current submission also includes emissions from flooded land in Thessaly, as a result of extreme rainfall in September 2024.

Table 6.26 Net GHG emissions/removals (in kt) from Wetlands for the period 1990 – 2023

IPCC categories	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Wetlands remaining wetlands											
CO_2	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to wetlands											
CO_2	NO	NO	0.04	0.70	0.26	0.08	0.20	0.57	2.16	0.33	2.51
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	NE,NO	NE,NO	0.04	0.71	0.26	0.08	0.21	0.58	2.18	0.35	2.55

IPCC categories	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Wetlands remaining wetlands											
CO_2	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to wetlands											
CO_2	0.74	2.38	1.37	26.31	3.10	4.25	3.60	2.84	2.84	2.63	2.61
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	0.78	2.42	1.42	26.54	3.33	4.48	3.83	3.05	3.05	2.82	2.80

IPCC categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wetlands remaining wetlands											
CO_2	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

IPCC categories	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Land converted to wetlands											
CO_2	2.90	2.61	0.22	0.20	0.17	0.16	0.38	1.74	1.12	2.39	1.01
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total (kt CO_2 eq)	3.10	2.80	0.23	0.21	0.19	0.18	0.40	1.77	1.16	2.47	1.07

IPCC categories	2023
Wetlands remaining wetlands	
CO_2	NE,NO
CH_4	NO
N_2O	NO
Land converted to wetlands	
CO_2	53.07
CH_4	NO
N_2O	0.00
Total (kt CO_2 eq)	53.41

NO: Not Occurring; NA: Not Applicable; NE: Not Estimated

6.6.2 Methodology

Change in carbon stocks in living biomass

Carbon stock changes in lands converted to flooded lands are caused by decomposition of living biomass in these areas. The difference between initial and final living biomass carbon pools is used to calculate change in carbon stocks due to land use conversion. The equation used to estimate annual changes in carbon stocks in living biomass in land converted to wetlands is:

$$\Delta C_{LW_{LB}} = A \bullet (C_{After} - C_{Before})$$

where, $\Delta C_{LW_{LB}}$ is the annual change in carbon stocks in living biomass in land converted to wetlands, t C yr^{-1}, A is the area of land converted annually to wetland from some initial use, $hayr^{-1}$, C_{After} is the carbon stocks in living biomass immediately after conversion to wetlands, t C ha^{-1}, C_{Before} is the carbon stocks in living biomass immediately before conversion to wetlands, t C ha^{-1}.

The average carbon stock in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock B_W of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground biomass stocks were approximated using the default root-shoot ratio. It is assumed that the carbon stock prior to the conversion is lost in the first year following conversion ($C_{After} = 0$).

Greece reports on carbon stock changes in living biomass and soils in cropland converted to wetlands for the first time in the current submission. The default biomass carbon stock value (4.7 t C ha-1) for croplands (CBefore), as proposed by the 2006 GL AFOLU, has been used.

Actual areas converted annually have been used for each unit of land converted to Wetlands. These data were provided by the local Forest Service disaggregated by initial land use and vegetation type until 2023. In the current submission geographically explicit data have been used to estimate the relevant areas, as described in ***Section 6.2***.

Change in carbon stocks in dead organic matter – soil organic matter

CO_2 emissions from dead organic matter and soil organic matter associated with Forest land and Grassland conversion to Flooded lands are addressed in this category. The methodology applied follows the Tier 1 approach of the GPG LULUCF (Appendix 3a.3), according to which CO_2 emission from flooded lands occur via the molecular diffusion across the air-water interface after flooding has occurred. This is a simplified approach to estimating emissions using default emission data, and area data converted annually provided by the local Forest Service, based on the equation:

$$CO_{2\ emissions_{WW\ flood}} = P \bullet E(CO_2)_{diff} \bullet A_{flood,\ total\ surface}$$

where, $CO_{2\ emissions_{WW\ flood}}$ is the total CO_2 emissions from flooded lands, Gg CO_2 yr^{-1}, P is the period, days, $E(CO_2)_{diff}$ is the averaged daily diffusive emissions, Gg CO_2 ha^{-1} day^{-1}, $A_{flood,\ total\ surface}$ is the total flooded surface area, including flooded land, flooded lake and flooded river surface area, ha.

The method described in the previous section for the estimation of carbon stock changes in aboveground living biomass due to land conversion to flooded land assumes that all aboveground biomass is converted into CO_2 in the first year following the conversion. According to the GPG LULUCF, in actuality, the part of the above ground biomass that is left on site before flooding will decompose more slowly, while decay of soil carbon will also contribute to the emissions. These CO_2 emissions were estimated using the equation above, during the ice–free and ice-cover periods, encompassing both emissions from dead organic and soil organic matter.

The 365 days period, and the CO_2 emission factors via the diffusion pathway for the ice-free period for the entire year were used (Tier 1). Given the high uncertainty of the estimations of that method, and the considerable range of values between the diffusion emission factors provided by the GPG LULUCF for the temperate climate zone (-3.1 and 13.2 kg CO_2 ha^{-1} day^{-1}, table 3A.3.5), the respective factors provided by the 2006 GL AFOLU (table 2A.2, Appendix 2) were chosen instead, and more specifically a weighted average value for the whole of the country ($E(CO_2)_{diff}$ = 80% • 5.2 + 20% • 8.1 = 5.78 kg CO_2 ha^{-1} day^{-1}).

The default assumption that the CO_2 emissions are limited to 10 years after the flooding took place, was made.

Table 6.27 Net CO_2 emissions / removals (kt CO_2 eq.) from Land converted to Wetlands by subcategory for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Land converted to Wetlands	NO	NO	0.04	0.70	0.26	0.08	0.21	0.57	2.16	0.33	2.51	0.74
Biomass	NO	NO	0.04	0.63	0.18	0.00	0.12	0.44	1.83	NO	1.97	0.18
Dead Organic matter	NO	NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
Soils	NO	NO	0.00	0.07	0.08	0.08	0.09	0.13	0.33	0.33	0.54	0.56

IPCC category	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Land converted to Wetlands	2.38	1.37	26.31	3.10	4.25	3.60	2.84	2.84	2.63	2.61	2.91	2.61
Biomass	1.78	0.80	23.31	0.08	1.19	0.57	NO	NO	NO	NO	0.29	NO
Dead Organic matter	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
Soils	0.60	0.57	3.00	3.02	3.06	3.03	2.84	2.84	2.63	2.61	2.62	2.61

IPCC category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Land converted to Wetlands	0.22	0.20	0.17	0.16	0.38	1.74	1.11	2.40	1.01	53.07
Biomass	NO	NO	NO	NO	NO	1.33	0.48	1.59	0.18	49.14
Dead Organic matter	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
Soils	0.22	0.20	0.17	0.16	0.38	0.41	0.63	0.81	0.83	3.93

NO: Not Occurring, IE: Included Elsewhere

6.6.3 Uncertainty and time series consistency

Uncertainty estimates for the whole inventory period (1990-2020) have been assessed following Approach 1 of the 2006 GL AFOLU. Input uncertainties related to activity data and emission factors have been assessed on the basis of information provided mainly from the 2006 GL AFOLU and country specific information.

In ***Table 6.28*** below, the associated uncertainties with the above-mentioned parameters for land converted to flooded land are presented.

Table 6.28 Parameter uncertainties values

	%	Source
Area	10	Expert judgment based on country specific information
R	77	2006 GL AFOLU

Forest land/grassland above ground biomass	56	2006 GL AFOLU
EF for diffusive emissions	124	2006 GL AFOLU
Carbon fraction of dry matter	2	2006 GL AFOLU

The uncertainty assessment has been performed using equations 3.1, and 3.2 as contained in volume 1 of the 2006 GL AFOLU following the complete estimation process implemented in the inventory for estimating GHG emissions/removals.

The overall uncertainty for land converted to wetlands is equal to 43%. A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

6.7 Settlements (CRT Source Category 4E)

6.7.1 Category description

Settlements include all developed land, including transportation infrastructure and human settlements of any size, unless they are already included in other land-use categories.

For Settlements remaining Settlements category the tier 1 approach has been followed for living biomass, dead organic matter, and soil organic matter. According to this approach, there is no change in carbon stocks in living biomass pool, with the growth balancing losses. Similarly, dead wood and litter stocks are in equilibrium. Finally, it is assumed that inputs equal outputs so that no carbon stock changes occur in soils in settlements remaining settlements.

Changes in living biomass and soil organic matter associated with Forest land, Cropland, and Grassland conversion to Settlements, as well as carbon stock changes in dead organic matter in Forest land converted to Settlements are addressed in the remaining of this chapter.

Table 6.29 Emissions / removals of greenhouse gases (in kt) from Settlements for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Settlements															
CO_2	49.74	54.76	55.07	58.80	62.90	64.24	77.95	72.54	75.52	81.96	89.96	89.58	94.25	111.79	106.05
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Total (kt CO_2 eq)	50.08	55.39	55.97	59.96	64.33	65.93	79.93	74.78	78.02	84.75	93.05	92.95	97.91	115.80	110.36

IPCC category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Settlements															
CO_2	115.06	115.37	119.25	121.08	122.24	121.34	119.89	131.89	121.00	118.99	120.37	133.56	131.49	131.71	125.95
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total (kt CO_2 eq)	119.72	120.35	124.53	126.65	128.09	127.16	125.69	137.77	126.88	124.85	126.25	139.48	137.49	137.80	132.07

IPCC category	2020	2021	2022	2023
Settlements				
CO_2	124.65	124.63	121.77	117.11
CH_4	NO	NO	NO	NO
N_2O	0.02	0.02	0.02	0.02
Total (kt CO_2 eq)	130.77	130.76	127.07	122.41

NO: Not Occurring

6.7.2 Methodology

Change in carbon stocks in living biomass

The amount of C stock change in living biomass in land that is cleared for expanding settlements is estimated by multiplying the area converted annually to settlements by the difference in carbon stocks between biomass in the land prior to conversion (C_{Before}) and that in the settlements after conversion (C_{After}). The equation used to estimate annual changes in carbon stocks in living biomass in land converted to settlements is:

$$\Delta C_{LS_{LB}} = A \bullet (C_{After} - C_{Before})$$

where, $\Delta C_{LS_{LB}}$ is the annual change in carbon stocks in living biomass in land converted to settlement, t C yr^{-1}, A is the area of land converted annually to settlement from some initial use, ha yr^{-1}, C_{After} is the carbon stocks in living biomass immediately after conversion to settlement, t C ha^{-1}, C_{Before} is the carbon stocks in living biomass immediately before conversion to settlement, t C ha^{-1}.

The assumptions that have been followed are that all living biomass present before conversion to settlements is lost in the same year as the conversion takes place, and that carbon stocks in living biomass following conversion (C_{After}) are equal to zero.

Three types of land use changes to settlements have been identified:

- Forest land converted to Settlements
- Cropland converted to Settlements
- Grassland converted to Settlements, and
- Other land converted to Settlements

The average carbon stock in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock B_W of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground biomass stocks were approximated using the default root-shoot ratio.

Following previous ERT's recommendation, Greece reports on carbon stock changes in living biomass and in soils in cropland converted to settlements. The default biomass carbon stock value (4.7 t C ha^{-1}) for croplands (C_{Before}), as proposed by the 2006 GL AFOLU, has been used.

Until 2020 actual areas converted annually have been used for each unit of land converted to settlements. These data were provided by the local Forest Service disaggregated by initial land use and vegetation type. For the case of cropland conversion to settlements, the land areas converted have been derived by the utilization of the Corine Land Cover database. In the current submission

geographically explicit data have been used to estimate the relevant areas, as described in ***Section 6.2.***

Change in carbon stocks in dead organic matter

For the estimation of carbon stock changes in dead organic matter in forest land converted to settlements, the methodology applied is consistent with the 2006 GL AFOLU , according to which two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), t C yr^{-1}, ΔC_{DW} is the change in carbon stocks in dead wood, t C yr^{-1}, ΔC_{LT} is the change in carbon stocks in litter, t C yr^{-1}.

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{DOM} = (C_n - C_o) \cdot A_{on}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr^{-1}, C_o is the dead wood/litter stock under the old land use category, t C ha^{-1}, C_n is the dead wood/litter stock under the new land use category, t C ha^{-1}, A_{on} is the area converted from forest land to settlements, ha.

It is assumed that all carbon contained in dead wood and litter is lost during conversion and that there is no subsequent accumulation of new dead organic matter in the settlements after conversion. Dead wood and litter stocks following conversion are assumed to be equal to zero.

For the estimation of litter stocks prior to conversion, the data collected within the European project BioSoil in Greece (MEEN), were used (***Table 6.15***).

Since information about the dead wood stocks in Greece was not available, data obtained from a neighbouring country were used instead. Consequently, for the estimation of the dead wood carbon stocks prior to conversion the dead wood coefficients estimated on the basis of data collected in the framework of the Italian forest inventory per Italian region and per inventory typology were used instead (***Table 6.20***).

For the conversion of dry matter to carbon the IPCC factor (CF = 0.47) was used.

Change in carbon stocks in soils

Land conversion to Settlements occurs with development and expansion of cities and towns on former Forest land, Grassland, Wetlands, and Other land. These conversions change soil C stocks due to mechanical disturbance of the soil; soil burial or collection during development; type and amount of vegetated cover; in addition to the new management regime, particularly with respect to nutrient and water applications.

The change in soil C stocks in Forest land, Cropland and Grassland converted to Settlements was estimated using the equation 2.24 of the 2006 GL AFOLU with country specific data and IPCC default coefficients:

$$\Delta C_{LS_{Soils}} = \Delta C_{LS_{Mineral}} - \Delta C_{LS_{Organic}}$$

where, $\Delta C_{LS_{Soils}}$ is the annual change in carbon stocks in soils in forest land and grassland converted to settlements, t C yr^{-1}, $\Delta C_{LS_{Mineral}}$ is the annual change in organic carbon stocks in mineral soils, t C yr^{-1}, and $\Delta C_{LS_{Organic}}$, is the annual loss of carbon from drained organic soils, t C yr^{-1} in land converted to settlements. Since the areas of organic soils covered by forest in Greece are negligible and remain in a natural state, only emissions/removals for mineral soils have been considered.

Mineral soils

For mineral soils, the default method is based on changes in soil C stocks over a finite period of time. The change is computed based on C stock after the conversion relative to the carbon stock in a reference condition. The following assumptions were made:

- Over time, soil organic C reaches a spatially-averaged, stable value specific to the soil, climate, land-use management practices, and
- Soil organic C stock changes during the transition to a new equilibrium SOC occurs in a linear fashion.

The Tier 1 approach was followed using the equation 2.25 of the 2006 GL AFOLU:

$$\Delta C_{LS_{Mineral}} = [\,(SOC_0 - SOC_{(0-T)}) \cdot A] / D\ ,\ SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LS_{Mineral}}$ is the annual change in carbon stocks in mineral soils, t C yr^{-1}, SOC_0 is the soil organic carbon stock in the inventory year, t C ha^{-1}, $SOC_{(0-T)}$ is the soil organic carbon stock T years prior to the inventory year, t C ha^{-1}, T is the inventory time period, yr, A is the land area of each parcel, ha, D is the time dependence of stock change factors which is the default time period for transition between equilibrium SOC values, yr, SOC_{REF} is the reference soil organic carbon stock, t C ha^{-1}, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The default 20 years inventory time period and time dependence of the stock change factors was used. The initial (pre-conversion) soil C stocks were determined assuming that the F_{LU}, F_{MG}, F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks when a forest land converted to settlements, while for the cases of grassland conversions to settlements the $SOC_{(0-T)}$ was taken equal to 72.3 t C ha^{-1}. For the cases of cropland conversion to settlements the initial (pre-conversion) soil C stocks were determined using the same stock change factors as detailed in ***section 6.5.2.2***, namely F_{LU} = 0.78, F_{MG} = 1.03, F_I = 1.00. The current soil C stocks (SOC_0) on land converted to settlements were estimated using the stock change factors that apply to settlement area that is paved over (i.e. product of F_{LU}, F_{MG} and F_I equal to 0.8 times the corresponding product for the previous land use). For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece (***Table 6.21***).

In the following ***Table 6.30***, the net CO_2 emissions/removals from each pool are presented.

Table 6.30 Net CO_2 emissions / removals (kt CO_2 eq.) from Land converted to Settlements by subcategory for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Land converted to Settlements	49.74	54.76	55.07	58.80	62.90	64.24	77.95	72.54	75.52	81.96	89.96	89.58	94.25
Biomass	45.09	46.08	42.97	43.11	43.56	41.61	48.42	42.68	42.10	44.31	47.52	44.18	45.12
Dead Organic matter	0.13	0.36	0.25	0.36	0.41	0.29	3.38	0.22	0.32	0.87	1.67	0.94	0.83
Soils	4.52	8.33	11.85	15.33	18.93	22.34	26.15	29.64	33.09	36.79	40.78	44.46	48.30

IPCC category	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Land converted to Settlements	111.79	106.05	115.06	115.37	119.25	121.08	122.24	121.34	119.89	131.89	121.00	118.99
Biomass	54.39	46.85	52.40	48.35	47.66	45.62	44.55	44.43	43.04	51.28	42.93	41.43
Dead Organic matter	4.48	2.30	1.14	1.27	1.82	1.80	0.31	0.04	0.19	3.03	0.39	0.07
Soils	52.92	56.90	61.52	65.74	69.76	73.66	77.37	76.87	76.66	77.59	77.68	77.49

IPCC category	2015	2016	2017	2018	2019	2020	2021	2022	2023
Land converted to Settlements	120.37	133.56	131.49	131.71	125.95	124.65	124.63	121.77	117.11
Biomass	42.60	51.29	50.39	48.86	44.49	43.07	43.20	46.71	43.15
Dead Organic matter	0.13	4.06	1.89	2.47	0.61	0.61	0.35	1.42	0.03
Soils	77.65	78.21	79.21	80.38	80.85	80.97	81.08	73.65	73.92

6.7.3 Uncertainty and time series consistency

Uncertainty estimates for the whole inventory period (1990-2023) have been assessed following Approach 1 of the 2006 GL AFOLU. Input uncertainties related to activity data and emission factors have been assessed on the basis of information provided mainly from the 2006 GL AFOLU and country specific information.

In ***Table 6.31*** below, the associated uncertainties with the above-mentioned parameters for land converted to settlements are presented.

Table 6.31 Parameter uncertainties values

	%	Source
Area	10	Expert judgment based on country specific information
R	77	2006 GL AFOLU
Forest land/Grassland above ground biomass	56	2006 GL AFOLU
Carbon fraction of dry matter	2	2006 GL AFOLU
Average dead wood stock of forest areas	5	GHG Italy NIR 2016
Average litter stock of forest areas	72	2006 GL AFOLU

The uncertainty assessment has been performed using equations 3.1, and 3.2 as contained in volume 1 of the 2006 GL AFOLU following the complete estimation process implemented in the inventory for estimating GHG emissions/removals.

The overall uncertainty for land converted to settlements is equal to 27%. A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

6.8 Other land (CRT Source Category 4F)

6.8.1 Category description

The category Other land includes all land areas that do not fall into any of the other land-use categories (e.g. rocky areas, bare soil). In accordance with the 2006 GL AFOLU, changes in carbon stocks and non-CO_2 emissions were not assessed for the category Other land remaining Other land assuming that it is typically unmanaged. However, changes in carbon stocks associated with the conversion of Forest land and Grassland to Other land have been reported, since the act of conversion releases the carbon previously held on these lands.

Table 6.32 Emissions / removals of greenhouse gases (in kt) from Other land for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Other land														
CO_2	19.79	12.68	29.99	23.60	26.41	27.89	39.44	44.87	46.20	51.52	59.15	64.23	69.89	69.09
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Total (kt CO_2 eq)	20.16	13.23	30.96	24.78	27.82	29.45	41.37	47.28	48.98	54.66	62.56	67.97	74.01	73.55

IPCC category	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Other land														
CO_2	77.69	69.91	82.51	107.50	99.33	89.72	86.45	84.33	128.23	82.43	82.47	80.15	81.38	83.76
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total (kt CO_2 eq)	82.5	74.84	87.85	113.5	105.7	96.23	92.7	90.46	134.6	88.56	88.46	86.02	87.01	89.17

IPCC category	2018	2019	2020	2021	2022	2023
Other land						
CO_2	79.02	75.65	76.59	96.76	89.01	87.52
CH_4	NO	NO	NO	NO	NO	NO
N_2O	0.02	0.02	0.02	0.02	0.02	0.02
Total (kt CO_2 eq)	84.5	81.16	82.14	103.24	95.59	94.13

6.8.2 Methodology

Change in carbon stocks in living biomass

The difference between initial and final living biomass carbon pools is used to calculate change in carbon stocks due to land-use conversion. In accordance with guidance provided by 2006 GL AFOLU, the equation used to estimate annual changes in carbon stocks in living biomass in land converted to other land is:

$$\Delta C_{LOLB} = A \bullet (C_{After} - C_{Before})$$

where, ΔC_{LOLB} is the annual change in carbon stocks in living biomass in land converted to other land, t C yr^{-1}, A is the area of land converted annually to other land from some initial use, ha yr^{-1}, C_{After} is the carbon stocks in living biomass immediately after conversion to other land, t C ha^{-1}, C_{Before} is the carbon stocks in living biomass immediately before conversion to other land, t C ha^{-1}.

The average carbon stock in biomass in forest land and grassland immediately before conversion C_{Before} was obtained from the average biomass stock B_W of each vegetation type, as reported in the categories Forest land and Grassland, respectively. Belowground biomass stocks were approximated using the default root-shoot ratio. It is assumed that the dominant vegetation is removed entirely, resulting in no carbon remaining in living biomass after conversion. ($C_{After} = 0$).

Actual areas converted annually have been used for each unit of land converted to Other Land. These data were provided by the local Forest Service disaggregated by initial land use and vegetation type until 2020. In the current submission geographically explicit data have been used to estimate the relevant areas, as described in Section 6.2.

Change in carbon stocks in dead organic matter

The conversion to Other land from some initial land use may also cause changes to the carbon amount stored in dead organic matter and soils. Below the methodology applied for the estimation of emissions/removals from these carbon pools in forest land converted to other land is presented.

The assessment of carbon stock changes in dead organic matter in forest land converted to other land was made in accordance with the 2006 GL AFOLU. Two types of dead organic matter pools were considered: a) dead wood and b) litter:

$$\Delta C_{DOM} = \Delta C_{DW} + \Delta C_{LT}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead organic matter (includes dead wood and litter), t C yr^{-1}, ΔC_{DW} is the change in carbon stocks in dead wood, t C yr^{-1}, ΔC_{LT} is the change in carbon stocks in litter, t C yr^{-1}.

Each of the DOM pools was treated separately, but the method applied for each pool was the same.

For the estimation of carbon stock changes the Tier 1 methodology was followed, based on the equation:

$$\Delta C_{DOM} = (C_n - C_o) \cdot A_{on}$$

where, ΔC_{DOM} is the annual change in carbon stocks in dead wood or litter, t C yr^{-1}, C_o is the dead wood/litter stock under the old land use category, t C ha^{-1}, C_n is the dead wood/litter stock under the new land use category, t C ha^{-1}, A_{on} is the area converted from forest land to other land, ha.

It is assumed that no carbon remains in dead organic matter after conversion to Other land, and that all carbon stocks are assumed to be emitted in the year of conversion, thus there is no accumulation of DOM stocks (Tier 1). Consequently, dead wood and litter stocks following conversion are assumed to be equal to zero.

The litter stocks prior to conversion were calculated with the use of the data collected within the European project BioSoil in Greece (***Table 6.15***). For the estimation of the dead wood carbon stocks prior to conversion the dead wood coefficients estimated on the basis of data collected in the framework of the Italian forest inventory per Italian region and per inventory typology were used (***Table 6.16***). For the conversion of dry matter to carbon the IPCC factor (CF = 0.47) was used.

Change in carbon stocks in mineral soils

In accordance with the 2006 GL AFOLU, the change in carbon stocks in mineral soils in forest land and grassland converted to other land were estimated and reported. The estimation method for mineral soil is based on change in soil carbon stocks over a finite period following change in management that impacts soil carbon stocks, based on the equation 2.25:

$$\Delta C_{LOMineral} = [(SOC_0 - SOC_{(0-T)}) \cdot A] / T, \; SOC = SOC_{REF} \cdot F_{LU} \cdot F_{MG} \cdot F_I$$

where, $\Delta C_{LOMineral}$ is the annual change in carbon stocks in mineral soils in land converted to Other land, t C yr^{-1}, SOC_0 is the soil organic carbon stock in the inventory year, t C ha^{-1}, $SOC_{(0-T)}$ is the soil organic carbon stocks T years prior to the inventory year, t C ha^{-1}, T is the time period for the conversion, yr, A is the land area of each parcel, ha, SOC_{REF} is the reference soil organic carbon stocks, t C ha^{-1}, F_{LU} is the stock change factor for land-use or land-use change type, F_{MG} is the stock change factor for management regime and F_I is the stock change factor for input of organic matter.

The IPCC default time period for the conversion was used (T = 20). The initial (pre-conversion) soil C stocks were determined assuming that the $F_{LU,}$ F_{MG}, F_I stock change factors are equal to 1, and therefore the $SOC_{(0-T)}$ is equal to the reference (SOC_{REF}) soil C stocks when a forest land converted to other land, while for cases of grassland conversions to other land the $SOC_{(0-T)}$ was

taken equal to 72.3 t C ha^{-1}. The soil C stocks after conversion (SOC_0) were assumed to be zero for Other land (Tier 1). For the SOC_{REF} estimation, country specific data obtained from the Ministry of Rural Development and Food were used, and more specifically, the results from the Land Taxonomy Project of Greece (***Table 6.21***).

For the area of land converted to other land, direct annually estimates of spatially disaggregated areas were used. These data were provided by the local Forest Service for each land unit converted. In ***Table 6.33***, the net CO_2 emissions/removals from each subcategory are presented.

Table 6.33 Net CO_2 emissions / removals (kt CO2 eq.) from Land converted to Other land by subcategory for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Land converted to Other land	20.16	13.23	30.96	24.78	27.82	29.45	41.37	47.28	48.98	54.66	62.56	67.97
Biomass	12.55	4.61	12.83	6.15	6.24	5.48	10.56	10.23	7.89	8.26	11.83	10.34
Dead Organic matter	2.32	0.76	4.41	1.86	1.65	1.84	3.43	2.77	1.66	1.77	2.37	4.58
Soils	4.91	7.31	12.75	15.58	18.52	20.57	25.45	31.87	36.66	41.48	44.95	49.31

IPCC category	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Land converted to Other land	74.01	73.55	82.50	74.84	87.85	113.48	105.72	96.23	92.70	90.46	134.56	88.56
Biomass	12.33	8.14	10.24	3.79	9.93	19.62	12.97	3.1	3.23	2.47	34.53	1
Dead Organic matter	3.1	2.04	3.95	0.96	2.01	8.86	1.95	0.62	0.65	0.98	10.17	0.34
Soils	54.46	58.91	63.5	65.16	70.57	79.02	84.41	85.99	82.57	80.88	83.53	81.08

IPCC category	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Land converted to Other land	88.46	86.02	87.01	89.17	84.50	81.16	82.14	103.24	95.59	94.13
Biomass	2.76	2.15	5.61	11.08	6.53	2.73	2.42	10.19	1.82	0.17
Dead Organic matter	0.61	0.37	1.42	1.24	0.74	0.83	0.77	1.07	0.30	0.02
Soils	79.11	77.63	74.34	71.43	72.47	72.77	73.40	85.51	86.90	87.32

6.8.3 Uncertainty and time series consistency

Uncertainty estimates for the whole inventory period (1990-2023) have been assessed following Approach 1 of the 2006 GL AFOLU. Input uncertainties related to activity data and emission factors have been assessed on the basis of information provided mainly from the 2006 GL AFOLU and country specific information.

In ***Table 6.34*** below, the associated uncertainties with the above-mentioned parameters for land converted to other land are presented.

Table 6.34 Parameter uncertainties values

	%	Source
Area	10	Expert judgment based on country specific information
R	77	2006 GL AFOLU
Forest land/Grassland above ground biomass	56	2006 GL AFOLU
Carbon fraction of dry matter	2	2006 GL AFOLU
Average dead wood stock of forest areas	5	GHG Italy NIR 2016
Average litter stock of forest areas	72	2006 GL AFOLU

The uncertainty assessment has been performed using equations 3.1, and 3.2 as contained in volume 1 of the 2006 GL AFOLU following the complete estimation process implemented in the inventory for estimating GHG emissions/removals.

The overall uncertainty for land converted to other land is equal to 32%. A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

6.9 N_20 emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils

This section describes the method used to estimate the increase in N_2O emissions arising from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils.

The method used is consistent with the 2006 GL AFOLU following equations 11.1 and 11.8 from chapter 11, vol. 4.:

$$N_2O_{Direct} = N_2O\text{-}N_{N\ inputs} = F_{SOM} \bullet EF_1$$

where, $N_2O\text{-}N_{Direct}$ are the annual direct N_2O–N emissions produced from managed soils, kg N_2O–N yr^{-1}, $N_2O\text{-}N_{N\ inputs}$ are the annual direct N_2O–N emissions from N inputs to managed soils, kg N_2O–N yr^{-1}, F_{som} is the annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N yr^{-1}, EF_1 is the emission factor for N_2O emissions from N inputs, kg N_2O–N (kg N input)$^{-1}$.

$$F_{SOM} = \sum_{LU} [(\Delta C_{Mineral,\ LU} \bullet 1/R) \bullet 1000]$$

where F_{SOM} is the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N, $\Delta C_{Mineral,\ LU}$ is the average annual loss of soil carbon for each land-use type (LU), tonnes C, R is the C:N ratio of the soil organic matter

The default IPCC values for the EF_1 and the C:N ratio were used, namely 0.01 kg N_2O-N/kg N and 15, respectively.

N_2O emissions are reported following the conversion of forest land to grassland, cropland, wetlands, settlements and other land, as shown in Table 6.35.

Table 6.35 N2O emissions (kt CO_2 eq.) from N mineralization associated with loss of soil organic matter for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Forest land conv. to cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest land conv. to grassland	0.00	0.00	0.00	0.29	0.29	0.39	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.43	0.43
Forest land conv. to wetlands	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Forest land conv. to settlements	0.00	0.01	0.01	0.01	0.02	0.02	0.05	0.05	0.06	0.07	0.09	0.10	0.11	0.15	0.17
Forest land conv. to other land	0.14	0.17	0.36	0.44	0.51	0.60	0.77	0.91	0.99	1.07	1.22	1.38	1.51	1.62	1.81

IPCC category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Forest land conv. to cropland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest land conv. to grassland	0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.44	0.15	0.15	0.05	0.03	0.03	0.04	0.04
Forest land conv. to wetlands	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Forest land conv. to settlements	0.19	0.20	0.21	0.23	0.24	0.23	0.23	0.26	0.26	0.25	0.25	0.24	0.26	0.26	0.27
Forest land conv. to other land	1.86	1.95	2.38	2.47	2.50	2.39	2.41	2.78	2.72	2.69	2.63	2.54	2.49	2.63	2.40

IPCC category	2020	2021	2022	2023
Forest land conv. to cropland	0.00	0.00	0.00	0.00
Forest land conv. to grassland	0.04	0.03	0.04	0.03
Forest land conv. to wetlands	0.01	0.00	0.00	0.02
Forest land conv. to settlements	0.27	0.27	0.31	0.31
Forest land conv. to other land	2.44	2.50	2.51	2.51

N_2O emissions are reported following the conversion of grassland to cropland, wetlands, settlements and other land, as well as conversion of cropland to wetlands and settlements, as shown in Table 6.36.

Table 6.36 N2O emissions (kt CO_2 eq.) from N mineralization associated with loss of soil organic matter for the period 1990 – 2023

IPCC category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Grassland conv. to cropland	0.46	0.92	0.92	0.92	0.93	0.93	0.93	0.93	0.93	0.93	1.49	2.10	2.10	2.10	2.11
Grassland conv. to wetlands	NO	NO	NO	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.04	0.04	0.04	0.04	0.21
Grassland to settlements	0.09	0.12	0.13	0.14	0.16	0.17	0.17	0.19	0.19	0.21	0.25	0.26	0.29	0.34	0.36
Grassland other land	0.23	0.38	0.60	0.73	0.90	0.96	1.16	1.51	1.79	2.07	2.18	2.36	2.61	2.84	3.00
Cropland conv. to wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Cropland conv. to settlements	0.25	0.50	0.76	1.00	1.25	1.50	1.75	2.00	2.26	2.51	2.76	3.01	3.26	3.51	3.77

IPCC category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Grassland conv. to cropland	2.11	2.11	2.11	2.11	2.11	1.65	1.18	1.18	1.19	1.19	1.19	1.19	1.19	1.19	1.20
Grassland conv. to wetlands	0.22	0.22	0.21	0.20	0.20	0.19	0.19	0.19	0.19	0.00	0.00	0.00	0.00	0.00	0.02
Grassland. to settlements	0.44	0.50	0.53	0.56	0.58	0.54	0.52	0.57	0.58	0.56	0.57	0.61	0.68	0.76	0.78
Grassland other land	3.08	3.40	3.60	3.92	4.01	3.86	3.71	3.54	3.42	3.30	3.24	3.09	2.92	2.86	3.11
Cropland conv. to wetlands	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Cropland conv. to settlements	4.02	4.28	4.54	4.78	5.04	5.04	5.04	5.05	5.05	5.06	5.06	5.06	5.07	5.07	5.07

IPCC category	2020	2021	2022	2023
Grassland conv. to cropland	1.22	1.23	1.26	1.26
Grassland conv. to wetlands	0.02	0.05	0.04	0.04
Grassland. to settlements	0.71	0.79	0.81	0.82
Grassland other land	3.12	3.98	4.07	4.10
Cropland conv. to wetland	NO	0.00	0.01	0.28
Cropland conv. to settlements	5.08	5.08	5.08	5.09

6.9.1 Uncertainty and time series consistency

Uncertainty estimates for the whole inventory period (1990-2023) have been assessed following Approach 1 of the 2006 GL AFOLU. Input uncertainties related to activity data and emission factors have been assessed on the basis of information provided mainly from the 2006 GL AFOLU and country specific information.

The uncertainty for the area has been assessed equal to 10%, while for the EF_1 equal to 82%.

A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

6.10 Harvested wood products (HWP) (CRT Source Category 4G)

Annual carbon stock changes and CO_2 emissions and removals from the Harvested Wood Products pool are reported in this category. The methodology applied is consistent with Decision 2/CMP.7, and the guidance provided by 2006 GL AFOLU (chapter 12, vol. 4), and 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement).

More specifically, the production approach has been followed for the estimation of emissions/removals associated with carbon stock changes from HWP originating from the country's forest, using the tier 2 (First Order Decay) approach. The same methodology has been followed for estimating and reporting annual changes from that pool both under the UNFCCC and KP.

Three harvested wood products categories have been addressed, namely sawnwood, wood-based panels, and paper and paperboard. The necessary activity data for all three categories have been obtained from FAO statistics database, namely data for production, import and export.

Following ERT's recommendation Greece estimates the HWP contribution using activity data since 1900. For this purpose, the methodology proposed by 2006 GL AFOLU has been followed. More specifically, equation 12.6 has been applied with the estimated continuous rate of change in industrial roundwood consumption equal to 0.0151.

Carbon stocks and annual carbon stock changes have been estimated using the equation 2.8.5 of the KP Supplement:

$$\mathrm{C}(\mathrm{i}+1) = e^{-k} \bullet C(i) + \left[\frac{(1-e^{-k})}{k} \right] \bullet Inflow(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

where, i is the year, C(i) is the carbon stock in the particular HWP category at the beginning of year i, Gg C, k is a decay constant of FOD for each HWP category (HWPj) given in units yr^{-1} (k = ln(2)/HL, where HL is half-life of the HWP pool in years, Inflow (i) is the inflow to the particular HWP category (HWPj) during year i, Gg C yr^{-1}, and ΔC(i) is the carbon stock change of the HWP category during year i, Gg C yr^{-1}.

The change in carbon stocks was estimated separately for each product category. For the estimation of the annual fraction of the feedstock coming from domestic harvest for categories sawnwood and wood-based panels equation 2.8.1 of the KP Supplement has been used, and equation 2.8.2 for the estimation of annual fraction of domestically produced wood pulp as feedstock for paper and paperboard production:

$$F_{IRW}(i) = (IRW_P(i)-IRW_{EX}(i)) / (IRW_P(i)+IRW_{IM}(i)-IRW_{EX}(i))$$

$$F_{PULP}(i) = (PULP_P(i)- PULP_{EX}(i)) / (PULP_P(i)+ PULP_{IM}(i)-PULP_{EX}(i))$$

Where, $f_{IRW}(i)$ is the share of industrial roundwood for the domestic production of HWP originating from domestic forests in year i, $IRW_P(i)$ is the production of industrial roundwood in year i, Gg C yr^{-1}, $IRW_{IM}(i)$ is the import of industrial roundwood in year i, Gg C yr^{-1} and $IRW_{EX}(i)$ is the export of industrial roundwood in year i, Gg C yr^{-1}, fPULP(i) is the share of domestically produced pulp for the domestic production of paper and paperboard in year i, $PULP_P(i)$ is the production of wood pulp in year i, Gg Cyr^{-1}, $PULP_{IM}(i)$ is the import of wood pulp in year i, Gg Cyr^{-1} and $PULP_{EX}(i)$ is the export of wood pulp in year i, Gg Cyr^{-1}.

It is assumed that the HWP pool is in steady state at the initial time t_0, when the activity data start. For each HWP category the carbon stock in this steady state has been estimated using the following equation:

$$C(t_0) = Inflow_{average} / k$$

with,

$$Inflow_{average} = (\sum_{i=t0}^{t4} Inflow(i)) / 5$$

For the estimation of annual HWP amounts produced from domestic harvest the equation 2.8.4 was used:

$$HWPj(i) = HWP_P(i) \bullet f_{DP}(i)$$

where, $f_{DP}(i) = f_{IRW}(i)$ for HWP categories sawnwood and wood-based panels, and $(f_{IRW}(i) \bullet f_{PULP}(i))$ for HWP category paper and paperboard, with $f_{IRW}(i) = 0$ if $f_{IRW}(i)<0$ and $f_{PULP}(i) = 0$ if $f_{PULP}(i)<0$, $f_{DP}(i)$ is the share of domestic feedstock for the production of the particular HWP category originating from domestic forests in year i, HWPj(i) are the amounts produced from domestic harvest associated with activity j in year i, in m^3 yr^{-1} or M==t yr^{-1} and HWPp(i) is the production of the particular HWP commodities in year i, in m^3 yr^{-1} or Mt yr^{-1}.

For the estimation of emission factors for each HWP category the default half-lives values from table 2.8.2 of the KP Supplement, namely 2 years for paper, 25 years for wood panels, and 35 years for sawnwood have been applied, while default values presented in table 2.8.1 (KP Supplement) have been used as conversion factors for the default HWP categories.

It should be noted that a recalculation of the whole time-series has been performed in the current submission reflecting the recalculated activity data of the FAO statistics database for industrial roundwood, wood-based panels, wood-pulp, paper and paperboard categories.

Figure 6.6 presents the HWP in use for the whole period 1961-2023, while in ***Figure 6.7*** the annual change in stocks for the period 1990-2023 per each category is presented.

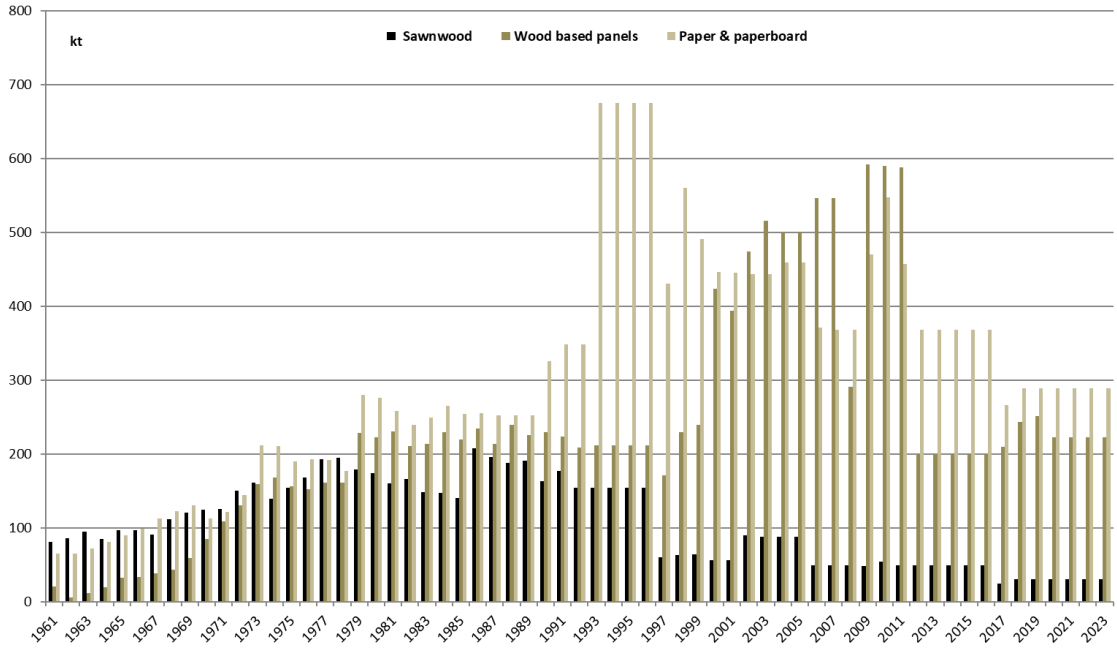


Figure 6.6 Harvested wood products in use

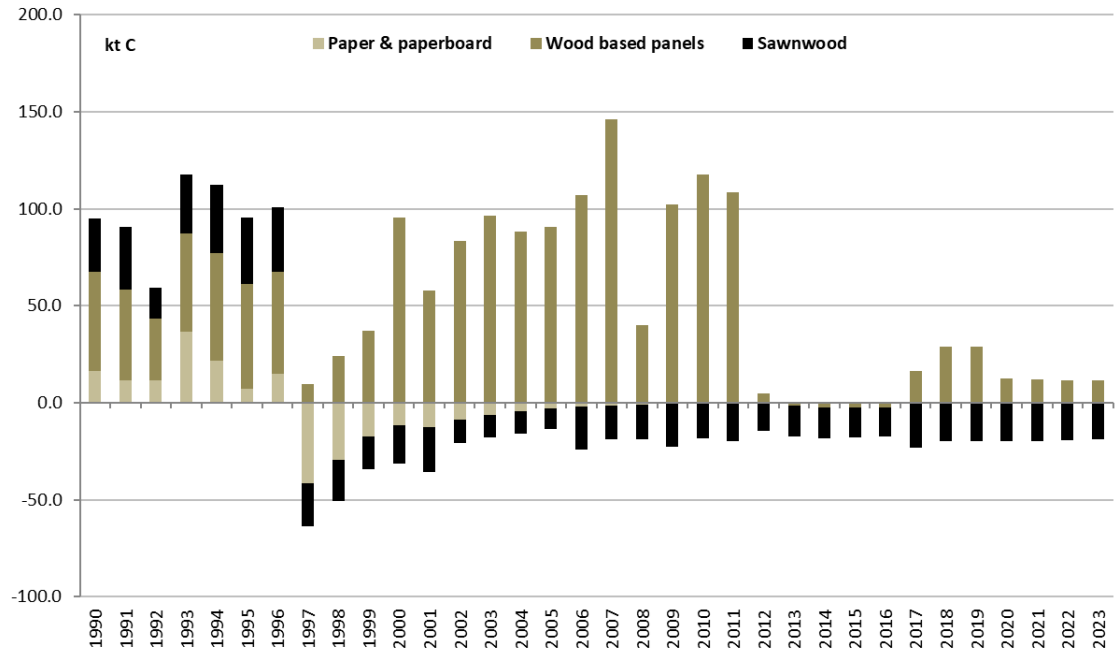


Figure 6.7 Annual change in carbon stocks (kt)

In the following ***Figure 6.8*** the production, import, and export quantities for the three HWP categories are presented.

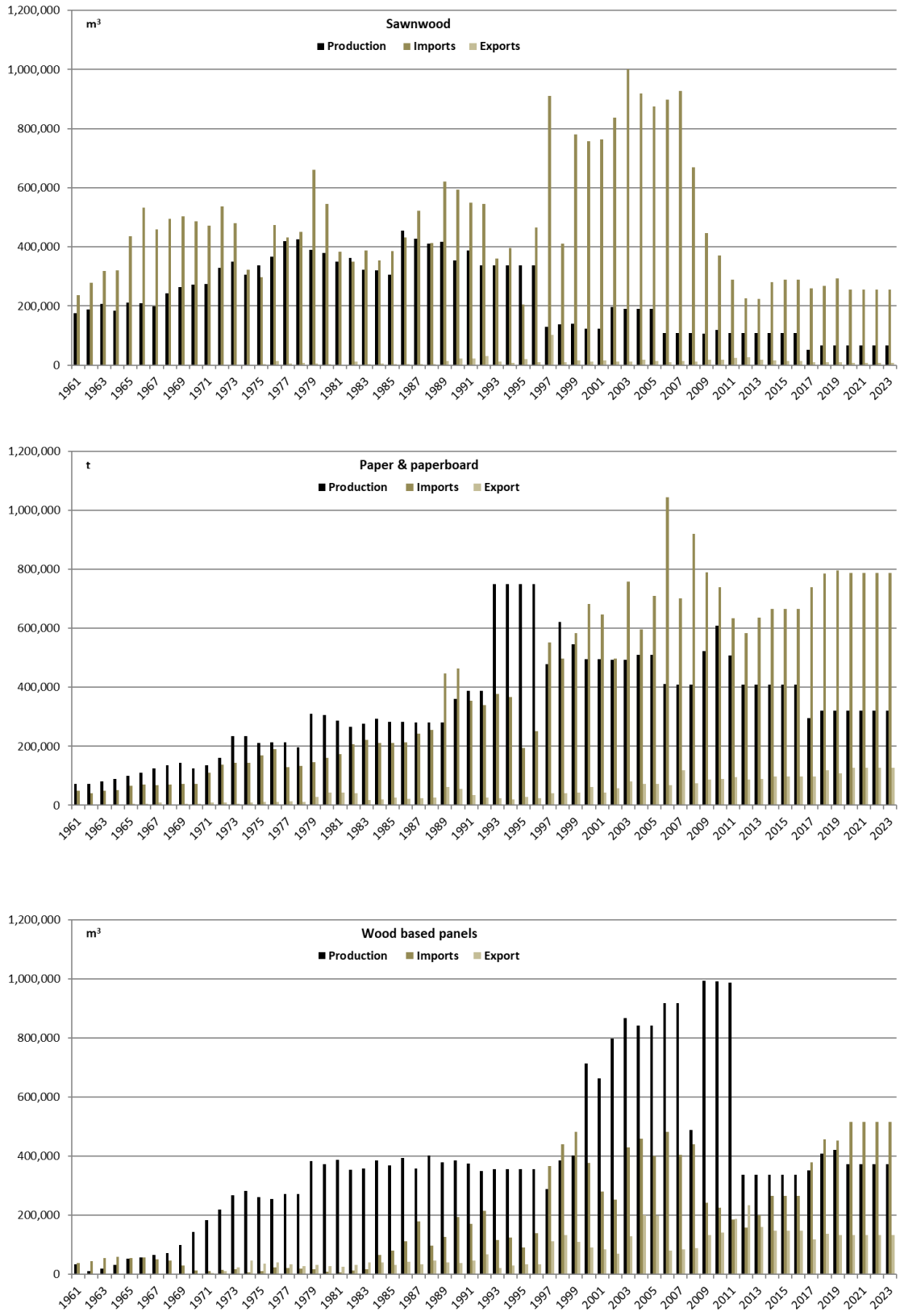


Figure 6.8 Production, imports, and exports in the HWP categories.

6.10.1 Uncertainty and time series consistency

The uncertainty associated with this category has been assigned based on information provided by 2006 GL AFOLU. In particular, the total uncertainty for the activity data equals to 15%, while the total uncertainty for the HWP pool equals to 50%.

A more detailed description of the results of the uncertainty analysis is reported in Annex IV.

7. Waste (CRT sector 5)

7.1 Overview

In this chapter the emissions of greenhouse gases from the sector *Waste* are presented and the relative methodologies of emissions calculation per source are described.

According to the IPCC Directives, the following source categories are included in this sector:

- Solid waste disposal on land
- Biological treatment
- Waste incineration
- Wastewater handling

The remainder of this chapter is organized as follows, Paragraph 7.1 continues with the presentation of emissions trends from the waste sector, a brief description of the methodology applied for the calculation of GHG emissions and the assessment of the completeness of the GHG inventory for the waste sector. Then (Paragraphs 7.2 – 7.5) detailed information on the methodologies applied (including references on the activity data and the emission factors used) for the calculation of GHG emissions per source of emissions is presented.

7.1.1 Emissions trends

In 2023 GHG emissions from *Waste* increased by 15.2% compared to 1990 levels (***Figure 7.1***). while the average annual rate of increase of emissions for the period 1990 – 2023 is estimated at 0.46%.

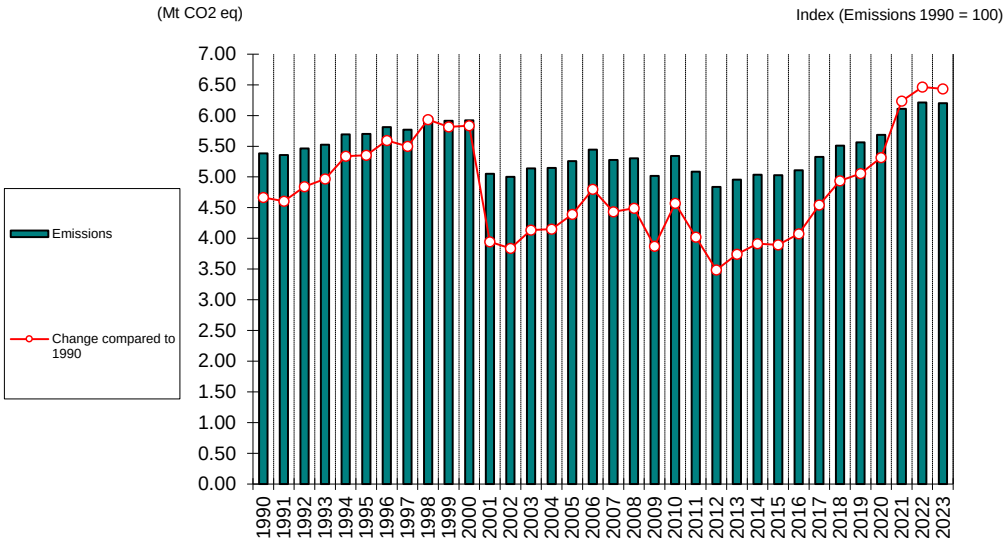


Figure 7.1 Total GHG emissions (in kt CO_2 eq) from Waste for the period 1990 – 2023

The sector *Waste* is responsible for carbon dioxide, methane and nitrous oxide emissions. GHG emissions from *Waste* per gas are presented in ***Table 7.1***.

Table 7.1 GHG emissions (in kt CO_2 eq) from Waste per gas for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
CH_4	5134.8	5103.3	5209.5	5266.1	5430.8	5436.1	5545.8	5498.1	5698.8	5634.0	5631.1
N_2O	248.9	252.4	255.6	256.9	262.0	264.2	265.5	269.6	268.9	279.5	291.7
Total	**5384.0**	**5356.0**	**5465.3**	**5523.2**	**5693.0**	**5700.5**	**5811.5**	**5768.0**	**5967.9**	**5913.7**	**5923.0**
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2	0.22	0.48	0.85	1.05	1.98	2.41	3.17	3.68	12.43	6.36	5.61
CH_4	4772.9	4725.7	4852.8	4860.3	4973.9	5159.8	4983.0	5015.4	4721.5	5046.9	4801.8
N_2O	277.7	274.6	284.8	284.6	280.1	283.7	289.2	282.7	282.6	286.6	278.9
Total	**5050.8**	**5000.8**	**5138.4**	**5145.9**	**5255.9**	**5445.9**	**5275.3**	**5301.8**	**5016.6**	**5339.9**	**5086.3**
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	3.48	3.83	4.48	5.48	4.66	4.26	3.78	3.40	3.57	3.87	4.16
CH_4	4558.3	4678.4	4758.3	4752.0	4833.7	5047.9	5226.1	5280.3	5418.5	5840.1	5948.8
N_2O	276.7	275.5	273.0	269.9	271.4	274.5	279.1	278.9	261.5	263.4	261.2
Total	**4838.5**	**4957.8**	**5035.7**	**5027.4**	**5109.7**	**5326.7**	**5508.9**	**5562.5**	**5683.5**	**6107.4**	**6214.1**
Year	2023										
CO_2	4.26										
CH_4	5934.8										
N_2O	260.8										
Total	**6199.8**										

Methane represents the major greenhouse gas from *Waste*, with a contribution which increased from 95.37% in 1990 to 95.73% in 2023. Overall, CH_4 emissions in 2023 increased by 15.6% compared to 1990 levels, with an average annual rate of 0.47%.

Greenhouse gases emissions from solid waste disposal on land present an increasing trend, with some fluctuations due to variations on the CH_4 recovered each year, while, on the contrary, emissions from wastewater handling are gradually decreasing. The decrease is mostly noticeable since 1999 because of the constant increase of wastewater volume treated under aerobic conditions, while since 2002 the rate of increase is slowing down.

As a result, the major source category from *Waste* (***Figure 7.2***) since 1999 is solid waste disposal on land. On the contrary, GHG emissions from wastewater handling present a declining trend.

Emissions from the incineration of clinical waste present a remarkable increase during the period 1990 – 2023; though the contribution of this source to total GHG emissions of the sector is negligible.

7.1.2 Methodology

The calculation of GHG emissions from *Waste* is based on the methodologies and emission factors suggested by the IPCC Guidelines and the IPCC Good Practice Guidance.

- Data on quantities of waste generated and sent to managed or unmanaged landfills is provided by the Directorate of Waste Management of the Ministry of Environment and Energy (MEEN) and the ELSTAT.
- Data on population used in the calculations are provided by the ELSTAT.
- The main sources of information for the necessary data and parameters are the Ministry of Environment and Energy (MEEN), the Association of Communities and Municipalities in the Attica Region (ACMAR), the Athens Water Supply and Sewerage Company (EYDAP) as well as various research studies and international databases.

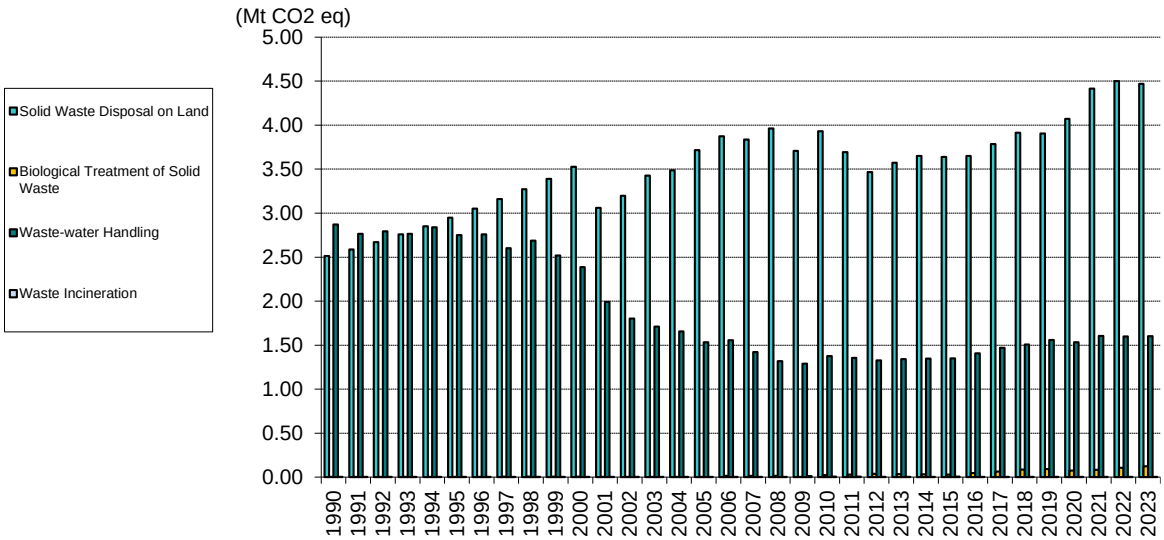


Figure 7.2 ***Greenhouse gases emissions (in kt CO_2 eq) from Waste per source category for the period 1990 – 2023***

The methodology applied for the calculation of emissions per source category is briefly presented in ***Table 7.2***, while a detailed description is given in Paragraphs 7.2 – 7.4.

Key categories

The following key categories are included in the sector *Waste* (***Table 7.3*** – see Paragraph 1.5 for a complete presentation of the results of the key categories analysis and Annex I for the presentation of the relevant calculations).

Table 7.2 Methodology for the estimation of emissions from waste

	CO_2		CH_4		N_2O	
	Methodology	Emission Factor	Methodology	Emission Factor	Methodology	Emission Factor
Solid waste disposal on land			T2	D, CS		
Biological treatment			D	D	D	D
Wastewater handling			D, CS	D, CS	D	CS
Waste Incineration	D	D, CS	D	CS	D	CS

T2: Tier 2 IPCC methodology
D: Default IPCC methodology / emission factor
CS: Country Specific

Table 7.3 Key categories from the Waste sector

Source category	Gas	Level assessment	Trend assessment
Solid waste disposal on land	CH_4	☒	☒
Wastewater handling	CH_4	☒	☒
Wastewater handling	N_2O	☒	

7.1.3 Completeness

Table 7.4 gives an overview of the IPCC source categories included in this chapter and presents the status of emissions estimates from all sub-sources in the waste sector.

Table 7.4 Completeness of the GHG inventory for the waste sector

	CO_2	CH_4	N_2O
A. Solid waste disposal on land			
1. Managed waste disposal on land	NO	☒	
2. Unmanaged waste disposal on land	NO	☒	
3. Disposal of sewage sludge	NO	☒	
4. Industrial solid waste (Managed SWDS)	NO	☒	
5. Industrial solid waste (Unmanaged SWDS)	NO	☒	

Construction and demolition waste (Managed SWDS)	NO	☒	
Construction and demolition waste (Unmanaged SWDS)	NO	☒	
B. Biological Treatment of Solid Waste			
1 Composting	NO	☒	☒
2. Anaerobic digestion at biogas facilities	NO	☒	NO
C. Wastewater treatment			
1. Industrial wastewater		☒	☒
2. Domestic and commercial wastewater		☒	☒
D Waste incineration			
1. Biogenic	NA	☒	☒
2. Hospital waste	☒	☒	☒
3. Other	☒	☒	☒

NO: Not Occurring, NA: Not Applicable

7.2 Solid waste disposal on land (CRF Source Category 5A)

7.2.1 Description

Solid waste disposal on land is responsible for methane emissions. Methane is emitted during the anaerobic decomposition of organic waste disposed of in various solid waste disposal sites (SWDS). The main characteristic of this process is that organic waste decomposes at a diminishing rate over time and takes many years to decompose completely. Moreover, other factors such as the type of waste disposed, the characteristics of the disposal sites and the climate conditions, affect the decomposition rate.

Carbon dioxide emissions occur during the flaring of biogas released from the decomposition of waste. However, these emissions should not be included in the total GHG emissions of the sector as they are of biogenic origin. Recovery and flaring of biogas constitute a waste management practice in the major managed SWDS of Greece since 1992. The amounts of biogas flared were estimated taking into account detailed data for biogas recovery in the largest SWDSs of the country from the national energy balance.

Methane emissions from solid waste disposal on land consist of emissions from municipal solid waste disposal on sites, emissions from sewage sludge (generated during municipal wastewater handling) landfilled and emissions from industrial solid waste and construction and demolition solid waste disposal in managed and unmanaged sites. Methane emissions for all the sub-categories were calculated using the First Order Decay (FOD) method (Tier 2)

The application of the FOD method requires historical data of several decades related to the waste generated, their composition over the years, the waste management practices applied and the specific conditions at the sites (e.g. organic matter, humidity, temperature). In Greece, there is no joint database for these data for all landfills, especially for historical data, while additional difficulties are created by the existence of a number of unmanaged waste disposal sites still operating. Therefore, the application of the FOD method was based on assumptions and estimations of certain parameters that were impossible to be calculated analytically for each waste disposal site.

For the municipal solid waste, for the period 2001-2022 the official data provided by the MEEN was used. Concerning the data for the period 1960-2000 total quantities of generated waste were estimated according to studies by the Directorate of Waste Management of the MEEN. As far as the annual sludge generated in the wastewater treatment facilities and the amounts landfilled in the SWDS, data derive from the MEEN, EYDAP and ACMAR. Finally, for the estimation of emissions from industrial solid waste and from construction and demolition solid waste, data from ELSTAT were acquired.

CH_4 emissions from solid waste disposal on land in 2023 accounted for 72.1% of total GHG emissions from Waste. The average annual rate of increase of emissions from solid waste disposal

on land, for the period 1990 – 2023 is estimated at 2.4%. CH4 emissions from managed and unmanaged solid waste disposal sites are presented in ***Table 7.5***.

Table 7.5 CH_4 emissions (in kt) from managed and unmanaged solid waste disposal

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Managed SWDS	2.80	5.56	8.32	11.05	13.93	16.85	19.82	22.90	26.19	29.72	34.00
Unmanaged SWDS	86.5	86.1	85.9	86.0	86.1	86.3	86.7	87.1	87.5	87.8	88.2
Sludge treatment	0.4	0.8	1.2	1.5	1.8	2.1	2.5	2.8	3.2	3.5	3.9
Total	89.7	92.5	95.4	98.5	101.8	105.3	109.0	112.9	116.9	121.1	126.0
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Managed SWDS	16.8	21.1	28.5	30.6	38.5	43.8	43.1	49.0	42.2	53.0	47.4
Unmanaged SWDS	4.2	4.6	5.0	5.5	6.1	6.9	7.1	7.3	7.8	7.9	7.9
Sludge treatment	88.2	88.4	88.8	88.5	88.1	87.7	86.8	85.2	82.4	79.5	76.6
Total	109.3	114.2	122.4	124.6	132.8	138.3	137.0	141.5	132.4	140.4	131.9
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Managed SWDS	42.3	48.7	54.0	56.0	58.7	65.7	72.7	74.8	83.1	97.7	103.4
Unmanaged SWDS	7.8	7.7	7.8	7.8	7.9	8.0	7.9	7.8	7.7	7.6	7.2
Sludge treatment	73.8	71.2	68.6	66.3	63.8	61.4	59.1	56.9	54.6	52.4	50.4
Total	123.8	127.6	130.4	130.0	130.4	135.2	139.7	139.5	145.4	157.6	160.8
Year	**2023**										
Managed SWDS	104.0										
Unmanaged SWDS	7.2										
Sludge treatment	48.4										
Total	159.6										

7.2.2 Methodology

The estimation of methane emissions from solid waste disposal on land is based on the application of the FOD method. The method was applied separately for the managed and unmanaged waste

disposal, taking account of the different conditions in those sites and the detailed information available regarding the opening and closure years of the operation of the managed sites. Calculations were based on the following main assumptions:

- Unmanaged wastes are considered to be landfilled in sites of similar characteristics concerning their composition and management (depth of sites), while the starting year of disposal and degradation of total unmanaged waste is assumed to be 1960.
- Managed SWDS started operating in 1990, according to the decision of 1986, Joint Ministerial Decision 4951/1424/1986, which was prepared for the implementation of the provisions of the European Directive 75/442/EU. The operation of the managed SWDS was reinforced in 1997 through the release of Joint Ministerial Decision 114218/1997 in which official provisions concerning the administrative procedures for the operation of the sites were issued.
- Industrial waste and construction and demolition solid waste is deposited in the same landfills as MSW and similar method was used for the estimation of its emissions.

The equations used for the estimation of CH_4 emissions are the following:

CH_4 generated at year t: $$P_t = \sum_{x=x_0}^{t} \left(A \cdot k \cdot MSW_T(x) \cdot MSW_F(x) \cdot Lo(x)\right) \cdot e^{-k \cdot (t-x)}$$

CH_4 emissions at year t: $$E_t = \left(P_t - R_t\right) \cdot \left(1 - OX\right)$$

$$Lo(x) = MCF \cdot DOC \cdot DOC_F \cdot F \cdot 16/12$$

Where, P_t is methane generation in the year t, E_t is methane emissions in the year t, A is the normalization factor which corrects the summation, k is the methane generation rate constant, MSW_T is the total municipal solid waste (MSW) generated, MSW_F is the fraction of MSW disposed at solid waste disposal sites, $Lo(x)$ is the methane generation potential, R is the recovered CH_4, OX is the oxidation factor, MCF is the methane correction factor, DOC is the degradable organic carbon, DOC_F is the fraction DOC dissimilated and F the fraction by volume of CH_4 in landfill gas.

Methane emissions from sewage sludge are also calculated separately using the FOD method, considering the specific characteristics related to the DOC, DOC_F and k parameters. The sludge content of the municipal waste disposed in the SWDS is not included in the waste composition used for the calculations of methane from municipal solid waste disposal on land.

The basic steps followed for the calculation of methane emissions are presented hereafter.

Generated quantities of municipal solid waste

At national level, there is a lack of confirmed official time-series of data regarding the composition and quantity of municipal solid waste (MSW) generated for the period up to 2000. Additional

difficulties arise from the fact that for the majority of the previous years, a large number of unmanaged SWDS existed. According to the Ministry of Environment and Energy (MEEN), 2182 unmanaged SWDS were still operating in 2000 (MINENV 2001). Following the National and Regional Planning of Solid Waste Management (first ones compiled in the end of 2003, national planning reviewed in 2015 and 2020), the process of closure and rehabilitation of unmanaged sites is in progress and is expected to be completed in the following years, along with the construction and operation of managed SWDS, following to the standards set by the EU directives, in order to cover the needs of the country. Nowadays, there is a small number of unmanaged WDS which is planned to be eliminated in the next years.

More accurate data for waste amounts generated in Greece and waste composition are available for the period 2001-2023.

The quantities of municipal solid wastes for the period 1960-2000 was estimated on the basis of population figures and coherent assumptions regarding generation rates per capita and day, in order to derive complete time series for waste quantities generated. For the rest of the period 2001-2023 more accurate data for the quantities of municipal solid wastes was used as they were provided by the corresponding Directorate of the Ministry of Environment and Energy (MEEN).

In ***Table 7.6*** the estimated data on population served for the whole period 1960-2023 is presented. Tourist population in permanent population terms is calculated by dividing by 365 the total annual tourist overnights spent by foreign tourists collected by the national statistical authority.

For the period 1960 – 1990 the per capita waste generation rate was considered in the range of 0.573 to 0.785 kg/ capita and day, showing a mean annual increase by 0.0085 kg/ capita and day.

For the period 1990 to 2000, figures 0.8 to 1.1 kg/ capita and day were assumed. These figures are based on estimated values by Ministry of Environment and Energy (MEEN) for 1997, and on an annually increase by 0.028 kg/ capita and day of annual per capita waste generation rate. This figure is calculated considering Greek legislation, ‘Measures and conditions for the management of solid waste - National and regional management planning’ (OGJ 723, July 2000) mentions that daily municipal solid waste generation per person is approx. 0.82 kg/person/day in 1991 and approx. 0.99 kg/person/day in 1997. Therefore in 6 years it is estimated that the rate increases by 0.028 kg/person/year.

For foreign visitors, 2.1 kg/ capita and day waste generation rate was considered. This figure is obtained by on expert judgments and it is based on the fact that tourist waste generation rate is more than the double of the permanent population generation rate.

These rates are derived from several studies that had been carried out in various regions of the country (e.g. Union of Local Authorities in the Prefecture of Attica 1996, MINENV 1999). In these studies, waste amounts and composition analysis was performed on a representative sample of typical garbage bins of various regions of Greece, in order to identify the total amount of waste generated in regions with known number of residents and visitors and the fraction of each component (Biowaste, Textiles, Wood, Paper, Plastics, Metals, Glass and Residual waste) on the total MSW quantity produced.

For the period 2001-2023, confirmed data were obtained from the Directorate of Waste Management of the Ministry of Environment and Energy (MEEN) and no assumption is used for the calculation of the generated quantities of municipal solid waste. In ***Figure 7.3*** it is illustrated how the data used for different parts of the time series relevant to generated quantities of municipal solid waste.

The average values of daily waste generation rates are presented In ***Table 7.7***.

Table 7.6 Total population served (in thousands)

Year	Permanent population	Tourists (in equivalent permanent)	Total population served
1960	8350.54	79.73	8430.27
1965	8540.59	81.75	8622.34
1970	8730.63	83.83	8814.46
1975	9157.35	85.96	9243.31
1980	9643.24	88.14	9731.38
1985	9948.21	97.24	10045.45
1990	10156.90	99.45	10256.35
1991	10256.29	83.62	10339.91
1992	10369.87	101.09	10470.96
1993	10465.53	101.67	10567.19
1994	10553.04	113.49	10666.53
1995	10634.39	106.22	10740.61
1996	10709.17	97.25	10806.43
1997	10776.50	108.80	10885.30
1998	10834.88	115.53	10950.41
1999	10882.58	124.61	11007.19
2000	10917.48	127.18	11044.66
2001	10949.96	119.05	11069.01
2002	10987.54	110.55	11098.09
2003	11019.04	110.71	11129.74
2004	11050.62	111.97	11162.60
2005	11103.92	111.60	11215.53
2006	11148.46	117.96	11266.42
2007	11192.85	131.73	11324.58
2008	11237.07	131.44	11368.50
2009	11282.75	127.88	11410.63
2010	11305.12	134.21	11439.33
2011	11123.39	149.36	11272.76
2012	11086.41	139.99	11226.39
2013	11003.62	158.21	11161.82
2014	10926.81	168.93	11095.73

2015	10858.02	176.34	11034.36
2016	10783.75	182.81	10966.56
2017	10768.19	203.68	10971.88
2018	10741.17	256.77	10997.94
2019	10724.60	256.37	10980.97
2020	10718.57	60.62	10779.19
2021	10678.63	161.63	10840.07
2022	10461.63	305.62	10767.24
2023	10413.98	337.28	10751.26

Table 7.7 Waste generation rates (kg/cap/day) of permanent population and tourists

Year	Permanent population	Tourists	Total population
1960	0.566	1.400	0.573
1965	0.611	1.530	0.620
1970	0.656	1.659	0.666
1975	0.697	1.789	0.707
1980	0.735	1.919	0.746
1985	0.772	2.048	0.785
1990	0.809	2.100	0.821
1991	0.816	2.100	0.827
1992	0.844	2.100	0.856
1993	0.872	2.100	0.884
1994	0.901	2.100	0.913
1995	0.929	2.100	0.940
1996	0.957	2.100	0.967
1997	0.985	2.100	0.996
1998	1.017	2.100	1.029
1999	1.050	2.100	1.062
2000	1.082	2.100	1.094
2001	1.118	2.100	1.128
2002	1.136	2.100	1.145
2003	1.150	2.100	1.159
2004	1.164	2.100	1.174
2005	1.176	2.100	1.186
2006	1.189	2.100	1.198
2007	1.200	2.100	1.210
2008	1.213	2.100	1.224
2009	1.228	2.100	1.237
2010	1.403	2.100	1.411
2011	1.348	2.100	1.358
2012	1.302	2.100	1.312
2013	1.286	2.100	1.297
2014	1.300	2.100	1.312

2015	1.297	2.100	1.310
2016	1.328	2.100	1.341
2017	1.338	2.100	1.352
2018	1.359	2.100	1.376
2019	1.384	2.100	1.400
2020	1.294	2.100	1.298
2021	1.349	2.100	1.360
2022	1.358	2.100	1.379
2023	1.364	2.100	1.388

**Data from 2001 and onward are not used on the calculations and they are presented only for completeness*

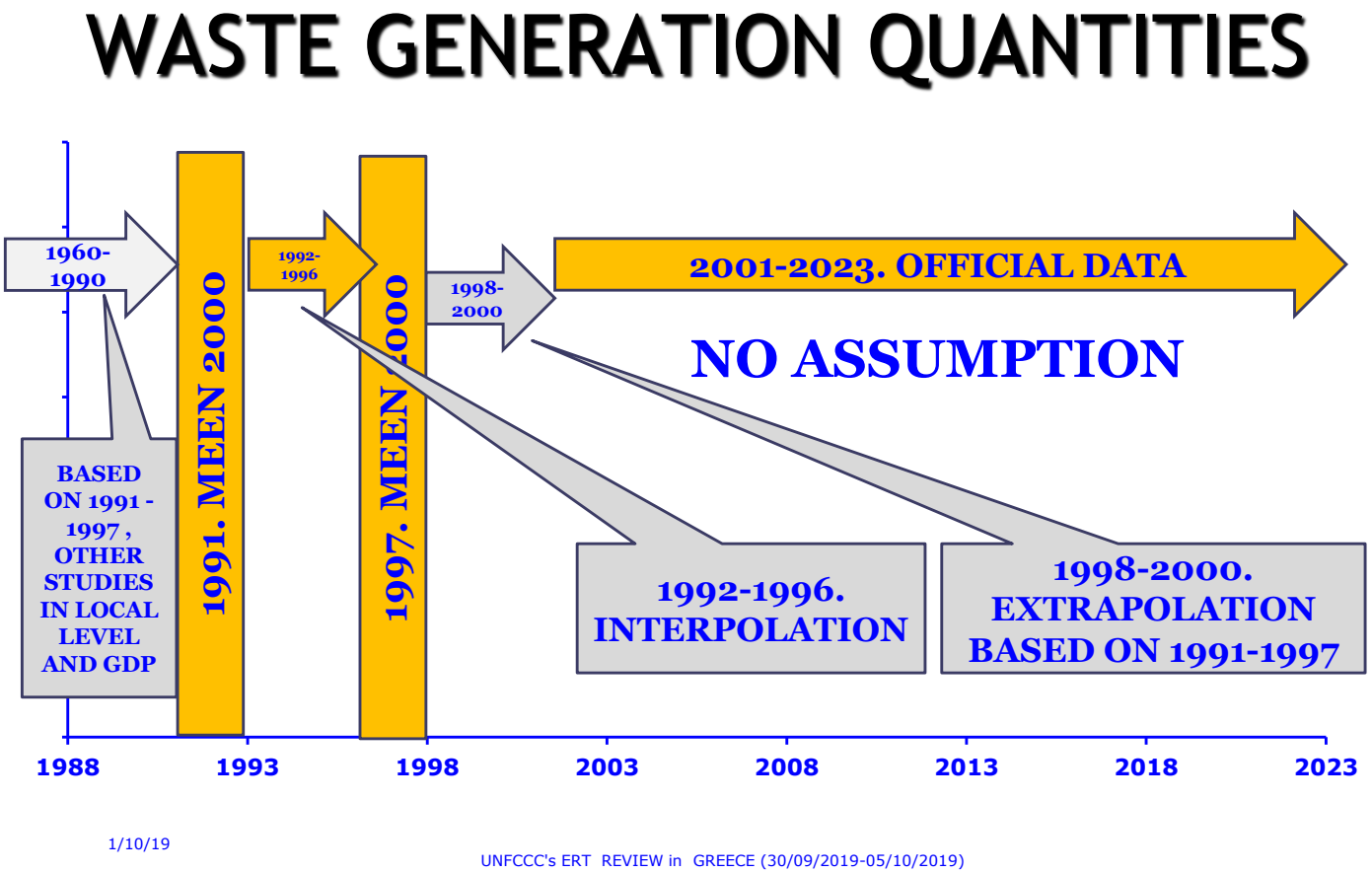


Figure 7.3 Generated quantities of municipal solid waste source for different parts of the time series

On the basis of the above, the following MSW quantities for the years 1990 – 2023 were estimated (***Table 7.8***).

Table 7.8 Quantities of MSW generated by year (in Mt)

Year	1960	1965	1970	1975	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
Generated MSW	1.765	1.951	2.142	2.384	2.651	2.877	3.075	3.119	3.273	3.41	3.556	3.686	3.815	3.958	4.112
Landfilled MSW	1.765	1.901	2.074	2.291	2.522	2.727	2.785	2.829	2.979	3.116	3.260	3.390	3.518	3.623	3.774
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Generated MSW	4.266	4.411	4.559	4.640	4.710	4.781	4.854	4.927	5.002	5.077	5.154	5.892	5.586	5.376	5.285
Landfilled MSW	3.927	4.070	4.157	4.233	4.328	4.298	4.295	4.295	3.999	4.180	4.181	4.878	4.578	4.507	4.421
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023					
Generated MSW	5.315	5.277	5.363	5.416	5.524	5.613	5.335	5.381	5.420	5.445					
Landfilled MSW	4.471	4.426	4.416	4.335	4.330	4.359	4.284	4.340	4.386	4.403					

Composition of generated municipal solid waste

As mentioned before, accurate data on the composition of municipal solid waste generated at national level were not available for the period up to 2000, as a comprehensive analysis at national scale covering a complete time period (so as to take into account seasonal variations because of tourist activity) has not been accomplished yet. However, measurements in some regions have been carried out, although they refer to different time periods (e.g. ULAPA 1996, MINENV 1999). For the period 2001-2023, more accurate data are provided by study issued by MEEN.

For the period 1960 – 1990 an annual increase (backwards) of 0.2% was assumed for biowaste, metals and glass are also assumed to increase (backwards) by 0.1% and 0.02% respectively, while paper and plastics are assumed to decrease annually (backwards) by 0.1% and 0.2% respectively.

As it was mentioned above, waste generated amounts and composition are derived from several studies that had been carried out in various regions of the country (e.g. Union of Local Authorities in the Prefecture of Attica 1996, MINENV 1999). In these studies, waste amounts and composition analysis was performed on a representative sample of typical garbage bins of various regions of Greece, in order to identify the total amount of waste generated in regions with known number of residents and visitors and the fraction of each component (Putrescibles, Textiles, Wood, Paper, Plastics, Metals, Glass and Rest) on the total MSW quantity produced. Composition of MSW at national level exists for 1997 (MEECC 1998).

Evolution of the waste composition for the period 1990-1997 is provided by the MEECC 2001a:

- The share of biodegradable decreases by 0.3% annually, while metals and glass decrease annually by 0.1% and 0.02% respectively.
- The share of paper and plastics increases by 0.2% annually.
- The share of garden (yard) waste, park waste and other non-food organic biowaste, wood and textiles remain constant.

For the period 1998-2009, the composition of MSW at national level for 1997 (MEECC 1998 and for 2009 ('Revision of National plan of waste management system', MEECC 2014) are utilized:

- The share of biodegradable decreases by 0.23% annually, while metals and glass are assumed to decrease annually by 0.05% and 0.016% respectively.
- The share of paper and plastics increase by 0.18% and 0.45% annually, respectively.
- The share of garden (yard) waste, park waste and other non-food organic biowaste, wood and textiles remain constant.

For the period 2010-2023, the official composition of MSW provided by the Ministry of Environment and Energy (MEEN) is utilized:

Table 7.9 Estimated composition (%) of MSW generated for the period 1990 – 2022

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food	49.10	48.80	48.50	48.20	47.90	47.60	47.30	47.00	46.78	46.55	46.33
Non-Food	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Textiles	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Wood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Paper	18.60	18.80	19.00	19.20	19.40	19.60	19.80	20.00	20.18	20.37	20.55
Plastics	7.10	7.30	7.50	7.70	7.90	8.10	8.30	8.50	8.95	9.40	9.85
Metals	5.20	5.10	5.00	4.90	4.80	4.70	4.60	4.50	4.45	4.40	4.35
Glass	4.64	4.62	4.60	4.58	4.56	4.54	4.52	4.50	4.48	4.47	4.45
Rest	9.61	9.63	9.65	9.67	9.71	9.73	9.75	9.41	8.73		8.73
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Food	46.10	45.88	45.65	45.43	45.20	44.98	44.75	44.53	44.30	43.75	43.21
Non Food	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.75	2.01
Textiles	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.25	3.14	3.02
Wood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.24	1.47
Paper	20.73	20.92	21.10	21.28	21.47	21.65	21.83	22.02	22.20	22.38	22.56
Plastics	10.30	10.75	11.20	11.65	12.10	12.55	13.00	13.45	13.90	13.90	13.90
Metals	4.30	4.25	4.20	4.15	4.10	4.05	4.00	3.95	3.90	3.88	3.86
Glass	4.43	4.42	4.40	4.38	4.37	4.35	4.33	4.32	4.30	4.28	4.26
Rest	8.38	8.04	7.70	7.36	6.68	6.33	5.99	5.65	5.67	5.70	4.97
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Food	42.66	42.12	41.57	41.03	40.48	39.94	39.39	38.85	38.30	38.30	38.30
Non Food	2.26	2.52	2.77	3.03	3.28	3.54	3.79	4.05	4.30	4.30	4.30
Textiles	2.91	2.80	2.68	2.57	2.45	2.34	2.23	2.11	2.00	2.00	2.00
Wood	1.71	1.95	2.18	2.42	2.65	2.89	3.13	3.36	3.60	3.60	3.60
Paper	22.75	22.93	23.11	23.29	23.47	23.65	23.84	24.02	24.20	24.20	24.20
Plastics	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90
Metals	3.85	3.83	3.81	3.79	3.77	3.75	3.74	3.72	3.70	3.70	3.70
Glass	4.25	4.23	4.21	4.19	4.17	4.15	4.14	4.12	4.10	4.10	4.10
Rest	5.72	5.74	5.76	5.79	5.81	5.83	5.85	5.88	5.90	5.90	5.90
Year	**2023**										
Food	38.30										
Non Food	4.30										
Textiles	2.00										
Wood	3.60										
Paper	24.20										
Plastics	13.90										
Metals	3.70										
Glass	4.10										

Rest	5.9

Quantities and composition of MSW at disposal sites

In order to estimate the quantities of MSW that end up at disposal sites (managed or unmanaged), data on the recycling of paper, aluminium, metals, plastics and glass in different regions were collected. Recycled quantities include also the part of biodegradable used for compost production. Recycled amounts are presented in ***Table 7.10***. To be noted that from 2007, paper recycled amounts increased due to investment of country to a more effective recycling system with increasing of collection and treating systems as well as of public awareness relevant to the importance of the recycling in environmental protection.

Table 7.10 Recovered amounts (kt) of MSW for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.5	31.5	31.5	31.5
Non-Food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Textiles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paper	250.0	250.0	250.4	250.8	251.0	251.8	252.0	252.7	253.6	253.3	253.7
Plastics	0.1	0.1	0.1	0.1	0.1	0.1	0.2	6.2	7.4	8.4	9.4
Metals	0.0	0.0	3.2	3.8	4.2	4.6	4.8	4.8	5.5	6.0	6.4
Glass	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Rest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.46	0.0
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Food	0.0	0.0	0.0	2.2	15.2	81.1	87.7	89.9	27.0	131.9	165.1
Non Food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Textiles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Paper	329.7	332.4	306.0	363.0	390.0	380.0	644.9	670.1	641.4	725.2	720.7
Plastics	8.0	8.5	9.0	9.5	10.1	10.7	11.3	12.0	12.7	13.4	22.0
Metals	10.3	11.1	12.0	13.0	14.0	15.2	16.4	17.7	19.2	20.7	26.6
Glass	44.0	45.0	45.0	45.0	45.0	45.0	32.0	47.1	62.9	62.9	62.9
Rest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Food	199.0	206.2	182.4	152.9	208.8	282.3	364.8	356.7	172.8	185.5	172.0
Non Food	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Textiles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	15.3	9.5	10.0
Paper	534.0	507.1	497.4	519.3	549.0	590.1	606.6	660.9	596.9	560.8	564.6

Plastics	30.6	39.2	47.7	56.3	64.9	73.5	82.1	90.6	99.2	112.6	113.3
Metals	32.4	38.3	44.1	50.0	55.8	61.7	67.5	73.4	79.2	77.6	78.2
Glass	62.9	62.9	62.9	62.9	62.9	62.9	62.9	62.9	87.2	95.7	96.4
Rest	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Year	2023										
Food	173.3										
Non Food	0.0										
Textiles	0.0										
Wood	10.0										
Paper	568.7										
Plastics	114.2										
Metals	78.7										
Glass	97.1										
Rest	0.0										

The estimated composition of the disposed municipal solid wastes in the two categories of SWDS (managed and unmanaged) is presented in ***Table 7.11***.

Table 7.11 Estimated composition (%) of MSW disposed for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food	54.22	53.80	53.28	52.76	52.24	51.76	51.29	50.48	50.13	49.77	49.43
Non-Food	1.66	1.65	1.65	1.64	1.64	1.63	1.63	1.64	1.63	1.63	1.63
Textiles	3.59	3.58	3.57	3.56	3.54	3.53	3.52	3.55	3.54	3.53	3.52
Wood	1.10	1.10	1.10	1.09	1.09	1.09	1.08	1.09	1.09	1.09	1.08
Paper	11.56	11.89	12.47	12.97	13.46	13.89	14.31	14.87	15.27	15.67	16.04
Plastics	7.84	8.04	8.24	8.42	8.61	8.80	9.00	9.12	9.55	10.00	10.44
Metals	5.74	5.62	5.39	5.24	5.10	4.98	4.85	4.78	4.70	4.63	4.56
Glass	3.69	3.68	3.71	3.73	3.75	3.76	3.76	3.81	3.83	3.83	3.84
Rest	10.61	10.62	10.60	10.58	10.57	10.56	10.55	10.65	9.85	9.46	9.85
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Food	50.56	50.29	49.68	50.0	49.9	48.7	51.2	51.3	51.5	49.6	49.1
Non Food	1.65	1.64	1.63	1.7	1.7	1.7	1.8	1.8	1.8	2.1	2.5
Textiles	3.56	3.56	3.54	3.6	3.6	3.7	3.9	3.9	3.8	3.7	3.7
Wood	0.86	0.86	0.86	0.9	0.9	0.9	1.0	1.0	0.9	1.3	1.6
Paper	14.81	15.08	15.89	15.1	14.9	15.7	10.6	10.6	11.5	12.0	11.8
Plastics	11.10	11.58	11.98	12.6	13.2	13.9	15.2	15.9	16.1	16.3	16.5
Metals	4.47	4.40	4.29	4.3	4.2	4.2	4.4	4.3	4.2	4.2	4.1
Glass	3.80	3.78	3.75	3.8	3.8	3.9	4.4	4.1	3.6	3.8	3.8

Rest	9.19	8.81	8.1	7.8	7.5	7.5	7.2	6.6	6.8	6.9	6.41
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Food	46.5	45.7	45.3	45.5	44.5	43.4	41.8	41.8	43.7	43.2	43.4
Non Food	2.7	3.0	3.3	3.6	4.0	4.4	4.8	5.2	5.4	5.3	5.3
Textiles	3.5	3.3	3.2	3.1	3.0	2.9	2.8	2.7	2.5	2.5	2.5
Wood	1.8	2.1	2.4	2.7	3.0	3.4	3.8	4.1	4.1	4.2	4.2
Paper	15.3	15.9	16.3	16.0	16.1	15.9	16.4	15.8	16.2	17.1	17.0
Plastics	15.9	15.7	15.5	15.3	15.4	15.7	15.8	15.8	15.0	14.6	14.6
Metals	3.9	3.7	3.5	3.4	3.3	3.3	3.2	3.1	2.8	2.8	2.8
Glass	3.7	3.6	3.6	3.6	3.6	3.7	3.8	3.9	3.1	2.9	2.9
Rest	6.8	6.9	6.9	6.9	7.1	7.3	7.5	7.6	7.3	7.3	7.3
Year	2023										
Food	43.4										
Non Food	5.3										
Textiles	2.5										
Wood	4.2										
Paper	17.0										
Plastics	14.6										
Metals	2.8										
Glass	2.9										
Rest	7.3										

For each managed SWDS of those sites, the start year of operation was taken into account, together with data and estimations on the quantities and composition of MSW generated in the areas served by those sites, as well as data on the quantities of recycled materials. The remaining part of MSW (after the subtraction of the corresponding quantities of the recycled materials in the remaining regions) is disposed at unmanaged disposal sites (***Table 7.12***).

The amount of dry sewage sludge disposed in the managed sites is also presented in ***Table 7.12***.

Table 7.12 Estimated quantities of MSW and sludge disposed (in kt) and Degradable Organic Carbon (DOC) per category (in kt)

Year	Managed SWDS	DOC – managed SWDS	Unmanaged SWDS	DOC – unmanaged SWDS	Sludge (dry)	DOC – sludge
1960			1764.55	284.18		
1965			1900.67	295.13		
1970			2073.38	319.70		
1975			2290.65	350.07		
1980			2522.02	380.77		
1985			2726.94	410.40		
1990	1160.08	167.33	1624.67	234.34	48.20	21.69
1991	1198.41	173.67	1630.78	236.33	48.20	21.69
1992	1246.11	182.41	1733.21	253.72	48.20	21.69
1993	1295.02	191.06	1820.73	268.62	48.20	21.69
1994	1406.12	209.04	1854.26	275.66	48.20	21.69
1995	1477.90	221.11	1911.78	286.03	51.62	23.23
1996	1544.44	232.50	1973.34	297.07	51.62	23.23
1997	1639.62	248.75	1983.06	300.85	61.00	27.45
1998	1799.82	274.90	989.84	151.19	59.32	26.69
1999	2005.12	308.30	1921.72	295.48	60.14	27.06
2000	2160.65	334.19	1909.25	295.31	66.34	29.85
2001	2336.78	351.90	1820.22	274.11	67.76	30.49
2002	2379.56	359.95	1853.55	280.38	77.65	34.94
2003	2423.82	372.12	1904.43	292.38	79.76	35.89
2004	2705.28	408.54	1633.48	246.68	83.40	37.53
2005	2824.04	424.35	1545.39	232.22	116.81	52.56
2006	2875.51	436.08	1509.70	228.95	125.98	56.69
2007	2805.07	382.52	1394.25	190.13	73.95	33.28
2008	3227.59	440.27	1002.81	136.79	71.63	32.23
2009	3939.36	551.29	441.55	61.79	109.21	49.15
2010	4563.64	644.90	364.00	51.44	64.00	28.80
2011	4312.79	609.61	265.67	37.55	47.11	21.20
2012	4241.83	646.36	265.00	40.38	40.62	18.28
2013	4156.25	645.60	265.00	41.16	48.78	21.95
2014	4205.90	663.92	265.00	41.83	54.88	24.70
2015	4160.94	658.87	265.00	41.96	50.95	22.93
2016	4215.70	670.89	200.00	31.83	67.93	30.57
2017	4185.24	666.34	150.00	23.88	68.02	30.61
2018	4180.00	672.94	150.00	24.15	41.68	18.75

2019	4258.72	683.22	100.00	16.04	39.84	17.93
2020	4234.18	674.13	50.00	7.96	36.26	16.32
2021	4289.70	690.60	50.00	8.05	36.10	16.25
2022	4336.17	695.64	50.00	8.02	28.81	12.96
2023	4353.43	717.12	50.00	8.24	29.46	13.26

The degradable organic carbon is estimated at 45% and the fraction of DOC dissimilated is estimated at 50%. The fraction of methane in the landfill gas released from sludge is 50%. Following 2019 in-country review recommendations, total sludge removed from domestic wastewater treatment, the amount landfilled, the amount used for spreading on agriculture soils and other sludge disposal are shown in ***Table 7.13***.

Table 7.13 Total sludge removed from domestic wastewater treatment, the amount landfilled, the amount used for spreading on agriculture soils and other sludge disposal (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Removed	48.2	48.2	48.2	48.2	48.2	51.6	51.6	61.0	59.3	60.1	66.3
Landfilled	48.2	48.2	48.2	48.2	48.2	51.6	51.6	61.0	59.3	60.1	66.3
Use in agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Removed	67.8	77.6	79.8	83.4	116.8	126.0	134.0	136.1	151.5	103.9	90.7
Landfilled	67.8	77.7	79.8	83.4	116.8	126.0	74.0	71.6	109.2	64.0	47.1
Use in agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.2
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.5	39.6	43.4	39.6
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Removed	90.0	113.0	116.1	113.3	119.8	110.5	105.8	101.2	92.1	98.5	99.1
Landfilled	40.6	48.8	54.9	51.0	67.9	68.3	41.7	39.8	36.3	36.1	28.8
Use in agriculture	9.4	22.6	22.7	22.6	14.2	7.5	21.1	21.4	22.4	4.95	23.5
Other	40.0	41.7	38.5	39.7	37.6	34.7	43.0	40.0	33.4	57.5	46.8
Year	**2023**										
Removed	101.3										
Landfilled	29.5										
Use in agriculture	24.7										
Other	47.1										

Biogas flaring

According to data from the MEEN, recovery and flaring of biogas constitute management practices in the 4 major managed SWDS of Greece (in the cities of Athens, Patra, Thessalonica and Larissa). For two of these sites, Athens and Thessalonica, biogas is used for energy generation. For the other two sites, Patra and Larissa, flaring of biogas constitutes management practice for environmental protection and not for energy recovery. From the National Energy balance (see attached data by National Energy balance), data are collected in Energy units, so for the transformation to methane mass recovered the proposed value of Net calorific value (50.4 TJ/Gg) by the IPCC 2006, CHAPTER 1 INTRODUCTION of Energy Chapter, Page 1.19, is used. In ***Table 7.14***, quantities of waste disposed in these two sites for which the CH_4 recovery is based on assumptions and the amount of methane obtained by the energy balance, are presented. For the rest of the sites that biogas is only flared, no CH_4 recovery is considered following the recommendation by the 2000 IPCC guidelines, Page 5.10. According to this recommendation 'The default value for methane recovery is zero. This default should only be changed when references documenting the amount of methane recovery are available. Recovered gas volumes should be reported as CH_4 not as landfill gas, as landfill gas contains only a fraction of CH_4. Reporting based on metering of all gas recovered for energy utilisation and flaring is consistent with good practice. The use of undocumented estimates of landfill gas recovery potential is not appropriate, as such estimates tend to overestimate the amount of recovery.'

It must be mentioned that during anaerobic digestion before sludge's stabilization and disposal, a quantity of biogas is recovered. However, this amount is not included in the total reported biogas recovery since it corresponds to gas recovery from the treatment of the whole amount of sewage sludge generated in Greece, before sludge's stabilization. To be noted that a significantly lower amount of stabilized sewage sludge is disposed, taking into consideration that a high amount of it, is transferred to other countries for energy use (incineration etc.). Thus, it is clear that a possible consideration of CH_4 recovery would result in underestimation of the emissions from the source.

In addition, "NE" notation key indicates that emissions / removal exist and they are not reported. In that case, as it is mentioned above, recovered CH_4 amounts correspond to sludge treatment before its stabilization and for a significantly higher amount than this finally disposed. For this reason, the methane emissions from the digested sewage sludge disposed in Greek managed SWDS are estimated and reported following the IPCC guidelines without any CH_4 recovery.

Table 7.14 CH_4 recovery from biogas flaring in managed SWDS

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CH_4 recovery in Athens and Thessalonica (kt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08	0.32	0.0

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CH_4 recovery in Athens and Thessalonica (kt)	23.77	23.61	20.04	23.06	19.64	19.23	24.58	23.51	38.43	33.63	45.99
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CH_4 recovery in Athens and Thessalonica (kt)	57.68	56.07	55.77	58.59	60.52	57.50	55.54	55.67	50.75	39.05	37.52
Year	**2023**										
CH_4 recovery in Athens and Thessalonica (kt)	40.67										

Industrial solid waste

Similarly with the municipal solid waste generated at national level, there are no available data for the industrial solid waste generated and disposed in sites for the whole of period of 1960 to 2023. Emissions from this source are estimated using the industrial waste amounts disposed in land provided by ELSTAT. These amounts are collected by the experts of ELSTAT based on individual researches (e.g. questionnaires sent to industries, etc).

It must be noticed that these data are provided by ELSTAT for the years 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018, 2020 and 2022. Thus, the historical data necessary for the rest of the years were estimated by using relative drivers i.e. the Greek GDP for the case of paper, wood and textiles and the Gross Production Value of livestock for the case of animal waste from food preparation and products, for the period 1960 to 2009. GDP evolution of Greece for the period 1960-2009 was obtained by the work 'THE GREEK ECONOMY IN THE 20TH CENTURY' of Prof. John Milios of National Technical University of Athens, while GPV of livestock was obtained from FAO.

For the period of 2005 to 2023, for the years that figures are not available, activity data are estimated following a simple interpolation (average value of the adjacent years).

According to the data provided by the ELSTAT., industrial waste, i.e. Animal waste from food preparation and products, Paper, Wood, Textiles, Mixed waste residues and Sorting waste residues are generated by the following manufacturing plants:

1. Manufacture of food products; beverages and tobacco products,

2. Manufacture of textiles, wearing apparel, leather and related products,

3. Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials,

4. Manufacture of paper and paper products; printing and reproduction of recorded media.

In ***Table 7.15*** quantities of Industrial solid waste disposed by year are presented.

Concerning the distribution of Industrial waste disposed to managed and unmanaged solid waste disposal sites, it is considered it is the same with this of the municipal solid waste taking into account that managed solid waste disposal sites started operating in Greece in 1990.

Table 7.15 Quantities of Industrial solid waste disposed by year (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food products	21.7	21.7	21.5	21.5	21.5	21.9	21.8	21.2	21.2	21.0	20.7
Textiles	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.3	2.4	2.5	2.6
Wood	1.7	1.7	1.8	1.7	1.8	1.8	1.8	1.9	2.0	2.0	2.1
Paper	12.7	13.1	13.2	13.0	13.3	13.5	13.9	14.4	14.8	15.3	16.0
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Food products	20.9	21.0	21.3	19.7	22.4	21.9	21.2	23.9	21.4	13.2	22.4
Textiles	2.7	2.8	3.0	3.0	3.2	4.4	3.5	3.0	3.5	2.9	1.7
Wood	2.2	2.3	2.4	1.4	2.6	0.9	2.8	4.1	2.9	4.6	2.8
Paper	16.7	17.3	18.2	19.1	19.7	15.1	21.4	27.4	21.6	21.0	18.3
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Food products	31.6	36.8	42.1	30.1	18.2	22.7	27.2	27.6	33.7	46.4	59.2
Textiles	0.4	0.4	0.4	0.6	0.9	0.6	0.2	0.3	1.5	0.9	0.2
Wood	1.1	1.1	1.1	1.1	1.1	1.1	0.9	1.0	0.4	0.4	0.3
Paper	15.7	16.1	16.4	11.2	5.9	4.6	3.3	3.3	1.2	2.5	3.9
Year	**2023**										
Food products	60.5										
Textiles	0.2										
Wood	0.3										
Paper	4.0										

Construction and demolition solid waste

Similarly with the MSW and the industrial solid waste generated at national level, there are no available data for the construction and demolition solid waste generated and disposed in sites for the whole of period of 1960 to 2023.

Figures for construction and demolition solid waste are provided by ELSTAT for the years 2006, 2008, 2010, 2012, 2014 and 2022. Thus, similar with industrial solid waste, the historical data necessary for the rest of the years were estimated by using relative drivers for the period 1960-

2005. Actually, the gross domestic product (GDP) was used as a key driver up to 1995, while for the remaining years of the time series the gross value added (GVA) was used because GVA data are not available for the years prior to 1995. For the period of 2007 to 2013, for the years that figures are not available, activity data are estimated following a simple interpolation (average value of the adjacent years), while for the period 2014-2023, the same approach with the period 1990-2005 is followed, utilizing relative economic drivers.

In ***Table 7.16*** disposed construction and demolition solid waste for the period 1990-2023 are provided.

Table 7.16 Disposed construction and demolition solid waste (in kt)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Wood	287.8	296.7	298.8	294.0	299.9	306.2	324.6	344.0	364.7	386.6	417.5
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Wood	450.9	487.0	525.9	568.0	613.4	662.5	662.5	662.5	665.4	202.1	176.9
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wood	78.7	62.6	46.5	46.3	46.2	46.9	47.6	48.3	43.4	48.8	49.4
Year	2023										
Wood	50.5										

As far as the distribution of construction and demolition solid waste disposed to managed and unmanaged solid waste disposal sites is concerned, it is considered that it is the same with the one of the municipal solid waste taking into account that managed solid waste disposal sites started operating in Greece in 1990.

Methane generation rate constant

The methane generation rate constant *k* is related to the time taken for the degradable organic carbon in waste to decay to half its initial mass:

$$k = \ln 2 / t_{1/2}$$

where $t_{1/2}$ is the time taken for the DOC in waste to decay to half its initial mass(“half life”) of waste during degradation process.

The estimation of *k* is determined by the conditions in the disposal sites (e.g. moisture content, temperature, soil type) and by the composition of waste land filled. Considering the fact that climate in Greece is dry temperate (the ratio of mean annual precipitation to potential evapotranspiration (MAP/PET) is around 0.5), "half life" was estimated at 17 years for paper and textiles, 35 for wood, 12 years for food waste, 14 years for non-food waste and 12 years for sewage sludge disposed on land.

Other parameters

- Methane Correction Factor (*MCF*): 1 for managed SWDS, 0.8 for unmanaged SWDS.
- Degradable organic carbon (*DOC*): 0.4 for paper (default value), 0.24 for textiles (default value), 0.43 for wood (default value), 0.15 for food waste (default value), 0.2 for non-food waste and 0.45 for sewage sludge.
- Fraction of DOC dissimilated (DOC_F) for solid waste. The default value of 0.5 was used.
- Fraction of DOC dissimilated (DOC_F) for sewage sludge 0.5.
- Fraction of methane in landfill gas (*F*): 50% (default value) for solid waste.
- Oxidation factor (*OX*): 0.1 for managed SWDS, 0.0 for unmanaged SWDS (default values)

7.2.3 Uncertainties and time-series consistency

The combined uncertainty of CH_4 emissions from unmanaged SWDS and managed SWDS for solid waste disposal as % of total emissions are estimated by 42%. The uncertainty associated with activity data and emission factors are 30% according to IPCC.

The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

7.2.4 Source-specific QA/QC and verification

Source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the waste sector are:

1. Cross checking information regarding waste quantities, composition and sewage sludge by Directorate of Waste Management of MEEN and by Association of Communities and Municipalities in the Attica Region (ACMAR).

2. Cross checking information provided by Directorate of Waste Management of Ministry of Environment and Energy (MEEN) and by the Ministry of Development, regarding the biogas recovered in MSW disposal sites which is used for energy generation.

3. Comparison of information regarding waste quantities, composition and sewage sludge with this for other countries.

4. Estimations were checked with several calculations tools with checking of emissions trends and sums deviations.

7.2.5 Recalculations

Updated activity data as far as the waste generation for the period 2021-2022 have been utilized, based on official data provided by the Ministry of Environment and Energy (MEEN).

The deviation of the CH_4 emissions from this category in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 7.17***.

Table 7.17 Recalculations of CH_4 emissions from solid waste disposal

Year	2021	2022
Difference (eq. CO_2 kt)	0.7	-12.3
Impact (%)	0.001	-0.016

7.2.6 Planned improvements

Further investigation regarding composition of disposed wastes is planned.

7.3 Biological treatment (CRF Source Category 5.B)

7.3.1 Methodology

Composting

For the estimation of CH_4 and N2O emissions from biological treatment - Composting of solid waste Tier 1 approach was used (IPCC, 2006), while the emission factors are the IPCC default ones.

In ***Table 7.18*** the amount of waste composted and emissions released for the period 1990 – 2023 are presented.

Table 7.18 Waste amounts (Dry matter in ktn) and emissions (in ktn) for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Waste amounts (Dry matter)								12.6	12.6	12.6	12.6
CH_4								0.13	0.13	0.13	0.13
N_2O								0.01	0.01	0.01	0.01
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Waste amounts (Dry matter)				0.9	6.1	32.4	35.1	35.9	10.8	52.7	66.1
CH_4	0.00	0.00	0.00	0.01	0.06	0.32	0.35	0.36	0.11	0.53	0.66
N_2O	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.03	0.01	0.04	0.04
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Waste amounts (Dry matter)	79.6	70.8	63.1	54.0	72.8	89.8	112.7	113.0	34.1	33.7	30.0	29.6
CH_4	0.80	0.71	0.63	0.54	0.73	0.90	1.13	1.13	0.34	0.33	0.30	0.30
N_2O	0.05	0.04	0.04	0.03	0.04	0.05	0.07	0.07	0.02	0.02	0.02	0.02

As it is observed by the Table above, the annual waste amount treated shows significant inter-annual changes, especially for the years:2004/2005 2005/2006, 2009/2010. This issue was raised during 2017 ERT review. It must be mentioned that official data provided by the Ministry of Environment and Energy are utilized for the estimation of the emissions from this sector. In any case composting in Greece is not performed in an extent basis and only small amounts of waste are composted.

In 2004, the total amount was only 2.2 tn while in 2005 and 2006 an increase is observed, i.e. 15 tn and 81 tn, respectively. Although a small increasing trend is observed for the rest years, in 2009 a significant decrease is noted due to significant operating problems on relevant industry units.

Anaerobic digestion at biogas facilities

For the estimation of CH_4 emissions from Biological treatment- 2. Anaerobic digestion at biogas facilities (5.B.2), the recommendation from IPCC 2006 was used, considering that the emissions of CH_4 from such facilities due to unintentional leakages during process disturbances or other unexpected events are the 5% of the amount of CH_4 generated.

In ***Table 7.19*** the amount of CH_4 for energy recovery and emissions released for the period 1990 – 2023 are presented.

Table 7.19 CH4 for energy recovery and emissions (in ktn) for the period 1990 – 2022

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Recovered	0.38	0.38	0.56	0.60	0.63	0.60	0.54	0.56	0.20	0.24	0.26
Emissions	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Recovered	0.54	0.54	0.48	0.24	0.24	0.20	0.22	0.16	0.18	0.54	1.13
Emissions	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.06
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Recovered	2.86	4.01	3.47	4.66	10.50	18.43	25.81	31.58	43.54	49.67	67.96
Emissions	0.14	0.20	0.17	0.23	0.52	0.92	1.29	1.58	2.18	2.48	3.40
Year	**2023**										
Recovered	78.42										
Emissions	3.92										

7.3.2 Recalculations

Updated activity data as far as the amounts of solid waste Composted for 2022 have been utilized.

The deviation of the CH_4 and N_2O emissions from this category in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 7.20***.

Table 7.20 Recalculations of CH_4 and N_2O emissions from solid waste disposal

Year	2022
	CH_4
Difference (eq. CO_2 kt)	-1.6
Impact (%)	-0.002
	N_2O
Difference (eq. CO_2 kt)	-0.9
Impact (%)	-0.001

7.4 Waste incineration (CRF Source Category 5C)

7.4.1 Description

Carbon dioxide, Methane and Nitrous oxide emissions from the incineration of clinical waste produced have been estimated. For the incineration of clinical waste, a central plant, the only existing in Greece, covers the total daily needs of hospitals.

Moreover, emissions from the incineration of biogenic agricultural residues produced in slaughterhouses and from the incineration of small amounts of industrial chemical waste are estimated. For these estimations, data provided by the Hellenic Statistical Authority as waste incinerated without energy recovery in Greece. These data were obtained by individual researches of ELSTAT.

Regarding open burning of waste it must be mentioned that in accordance to Greek legalisation (Combination of):

- Article 3 of JMD 11535/1993
- Prohibition of uncontrolled discharge and disposal of solid waste (Article 10 JMD 50910/2003, which has been repealed) and the obligation to provided waste to licensed body (Article 11 JDC 50910/2003, which has been repealed).
- Article 66 of Law 4819/2021 (OJG A 129), according to which the abandonment, dumping or uncontrolled management of waste, including littering, is prohibited.
- Establishment of conditions / criteria for waste incineration (now JMD 36060/2013, former JMD 22912/2005).

this activity is not allowed in Greece. For this reason, in category emissions from open burning of waste (5.C.2) the notation key “NO” is reported for all years of the time series in CRF table 5.C.

7.4.2 Methodology

For the estimation of CO_2 emissions from clinical waste and from industrial chemical waste, the default method suggested by IPCC Good Practice Guidance guidelines, was used. CO_2 emissions were not estimated for the agricultural residues taking into account that these were of biogenic nature. CH_4 and N_2O emissions were estimated using default methodology and default emission factors for all categories by IPCC 2006 Guidelines.

Data related to the amount of clinical waste incinerated derive from the ACMAR, which is operating the incinerator. For the other categories, data were collected by the ELSTAT for the 2004, 2006, 2008, 2010, 2012, 2016, 2018, 2020 and 2022 while for the rest of the years activity

data are estimated following an simple interpolation (average value of the adjacent years). For the 2023, for which activity data are not available, activity data are estimated through extrapolation (smooth increasing trend has been considered utilizing the given trend of the previous years when data were available).

The relevant parameters and emission factor used are the ones suggested in the IPCC Good Practice Guidance. Carbon Dioxide emissions were calculated based on the following equation:

$$CO_2 \text{ emissions} = CW \times CCW \times FCF \times EF \times 44/12$$

where, *CW* is the amount of clinical waste, *CCW* is the fraction of carbon content in the waste, 60% for clinical waste and 80% for chemical waste, *FCF* is the fraction of fossil carbon, 40% for clinical waste and 100% for chemical waste and *EF* is the burn out efficiency of combustion of the incinerator (95%).

Methane and Nitrous oxide emissions were calculated based on the following equation:

$$CH_4 \text{ emissions} = CW \times EF_{CH_4} \text{ and}$$

$$N_2O \text{ emissions} = CW \times EF_{N_2O}$$

while the emissions factors' values were 0.06 kg CH_4 / tn waste and 0.1 kg N_2O / tn waste for the CH_4 and for the N_2O, respectively, for all the waste incinerated, please refer to IPCC 2006 Guidelines, page 5.20 for CH_4 and page 5.22 for N_2O.

In ***Table 7.21*** the amount of waste incinerated and emissions released for the period 1990 – 2023 are presented.

It must be noted that as it is observed in this Table, amount of Non-biogenic wastes shows significant inter-annual changes for the years: 2001/2002, 2008/2009 and 2013/2014. This issue was raised during 2017 ERT review. It must be noted that Inventory Team has investigated these irregularities in collaboration with the waste experts from ACMAR and the national statistic authority of Greece and it seems that data are accurate given the fact that the same approach is utilized for the development of these values each year.

The increase on emissions for 2002, 2009 and 2014 are attributed on the installation of new infrastructures. In any case the impact of this subsector is minor in total GHG emissions from Greece.

Table 7.21 Waste amounts (in tn) and emissions (in tn) for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Clinical waste	180	180	180	180	180	180	180	180	180	180	180
CO_2	150	150	150	150	150	150	150	150	150	150	150
CH_4	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
N_2O	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
Biogenic (Agr. Residues)	3935	3935	3935	3935	3935	3935	3935	3935	3935	3935	3935
CH_4	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236
N_2O	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394	0.394
Other (Chem. Waste)	25	25	25	25	25	25	25	25	25	25	25
CO_2	70	70	70	70	70	70	70	70	70	70	70
CH_4	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
N_2O	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Clinical waste	180	492	939	1170	2231	2700	3666	4323	14819	7577	6691
CO_2	150	411	785	978	1865	2257	3065	3614	12388	6334	5593
CH_4	0.011	0.030	0.056	0.070	0.134	0.162	0.220	0.259	0.889	0.455	0.401
N_2O	0.018	0.049	0.094	0.117	0.223	0.270	0.367	0.432	1.482	0.758	0.669
Biogenic (Agr. Residues)	3935	3935	3935	3935	3439	2943	13771	24599	21064	17528	17528
CH_4	0.236	0.236	0.236	0.236	0.206	0.177	0.826	1.476	1.264	1.052	1.052
N_2O	0.394	0.394	0.394	0.394	0.344	0.294	1.377	2.460	2.106	1.753	1.753
Other (Chem. Waste)	25	25	25	25	40	54	40	25	16	8	7
CO_2	70	70	70	70	110	150	110	70	46	21	20
CH_4	0.002	0.002	0.002	0.002	0.002	0.003	0.002	0.002	0.001	0.000	0.000
N_2O	0.003	0.003	0.003	0.003	0.004	0.005	0.004	0.003	0.002	0.001	0.001
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Clinical waste	4135	4557	5316	6075	4653	4151	3553	3019	3138	3401	3665
CO_2	3457	3810	4444	5079	3890	3470	2970	2524	2623	2843	3064
CH_4	0.248	0.273	0.319	0.365	0.279	0.249	0.213	0.181	0.188	0.204	0.220
N_2O	0.413	0.456	0.532	0.608	0.465	0.415	0.355	0.302	0.314	0.340	0.366
Biogenic (Agr. Residues)	17528	18168	18807	10686	2564	2809	3055	3077	3100	3172	3245
CH_4	1.052	1.090	1.128	0.641	0.154	0.169	0.183	0.185	0.186	0.190	0.195
N_2O	1.753	1.817	1.881	1.069	0.256	0.281	0.305	0.308	0.310	0.317	0.324
Other (Chem. Waste)	7	7	13	145	276	284	292	316	340	367	394
CO_2	19	18	36	403	769	792	814	880	946	1023	1099
CH_4	0.000	0.000	0.001	0.009	0.017	0.017	0.018	0.019	0.020	0.022	0.024
N_2O	0.001	0.001	0.001	0.014	0.028	0.028	0.029	0.032	0.034	0.037	0.039

Year	2023
Clinical waste	3748
CO_2	3133
CH_4	0.225
N_2O	0.375
Biogenic (Agr. Residues)	3319
CH_4	0.199
N_2O	0.332
Other (Chem. Waste)	403
CO_2	1124
CH_4	0.024
N_2O	0.040

7.4.3 Uncertainties and time-series consistency

The uncertainty associated with activity data is 30% while the uncertainty associated with emission factors for all gases is 100% according to IPCC 2006.

The combined uncertainty of all emissions of waste incineration sector is estimated by 104.4%.

The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data in line with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

7.4.4 Source-specific QA/QC and verification

Source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the waste incineration sector are:

1. Cross checking information regarding waste incinerated obtained by operating the incinerators and by the ELSTAT.

2. Comparison of information emissions factors with this for other countries.

3. Estimations were checked with several calculations tools with checking of emissions trends and sums deviations.

7.4.5 Recalculations

Updated activity for the period 2019-2022 have been utilized.

The deviation of the CH4 and N2O emissions from this category in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 7.22***.

Table 7.22 Recalculations of CH4 and N2O emissions from solid waste disposal

Year	2019	2020	2021	2022
		CO_2		
Difference (eq. CO_2 kt)	0.04	0.51	0.55	0.66
Impact (%)	0.0001	0.0007	0.0007	0.0009
		CH4		
Difference (eq. CO_2 kt)	-0.0003	0.0009	0.0007	0.0007
Impact (%)	-6.3E-06	1.9E-05	1.4E-05	1.4E-05
		N_2O		
Difference (eq. CO_2 kt)	-0.005	0.015	0.011	0.011
Impact (%)	-6.3E-06	1.9E-05	1.4E-05	1.4E-05

7.5 Wastewater handling (CRF Source Category 5D)

7.5.1 Description

Domestic and industrial wastewater handling under anaerobic conditions produces CH_4. In Greece, domestic wastewater handling in aerobic treatment facilities shows a substantial increase since 1999, while in the industrial sector only a few units exist where wastewater is handled under anaerobic conditions.

N_2O emissions from industrial wastewater handling and from human consumption of food and their subsequent treatment through wastewater handling systems (indirect emissions) are also included in the wastewater handling source category.

Wastewater handling is a key category of CH_4 emissions, which have a substantial contribution in emissions trends (trend assessment). In ***Table 7.23*** CH_4 and N_2O emissions from wastewater handling for the period 1990 – 2023 are presented.

CH_4 emissions from domestic wastewater handling in 2023 decreased by 90% compared to 1990 levels while CH_4 emissions from industrial wastewater handling in 2023 increased by 28.1% compared to 1990 levels. The reduction of emissions from domestic wastewater handling is mainly due to the increased number of wastewater handling facilities under aerobic conditions. According to estimates provided by the Ministry of Environment and Energy (MEEN) the penetration of such facilities increased from 32% (of total population served) in 1999 and to 91.0% in 2023. N_2O emissions from human consumption of food and their subsequent treatment through wastewater handling systems (indirect emissions) increased by 2.0% compared to 1990 levels. N_2O emissions from industrial wastewater handling increased by 44.5% compared to 1990 levels.

Considering the fact that there are not sufficient data regarding all the wastewater handling facilities of the country and as a result methane emissions are calculated based on the total population serve. Emissions from domestic wastewater treatment and the sewage sludge removed from wastewater are not considered separately. However, as it is already mentioned in Paragraph 8.2, methane emissions from sewage sludge disposed in managed sites have been estimated. Therefore, in order to avoid double counting of emissions from sludge treatment, the organic load (in biochemical oxygen demand) of sludge that is actually disposed on land was subtracted by the organic load of wastewater treated.

Table 7.23 CH_4 and N_2O emissions (in kt) from wastewater handling

Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Domestic and commercial wastewater	CH_4	60.81	59.90	58.62	56.19	55.49	54.47	53.22	51.40	49.15	46.44	36.11
Human sewage	N_2O	0.92	0.93	0.95	0.95	0.97	0.98	0.98	0.99	0.99	1.03	1.07
Industrial wastewater	CH_4	32.83	29.88	32.00	33.35	36.63	34.34	35.85	31.95	37.34	33.57	38.85
Industrial wastewater	N_2O	0.018	0.017	0.018	0.018	0.020	0.019	0.021	0.019	0.021	0.019	0.021
Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Domestic and commercial wastewater	CH_4	20.73	17.73	14.52	11.09	9.26	7.89	6.95	6.81	6.58	6.52	6.33
Human sewage	N_2O	1.03	1.01	1.05	1.05	1.03	1.03	1.05	1.02	1.04	1.03	0.99
Industrial wastewater	CH_4	40.45	36.83	36.37	37.90	35.54	37.76	33.67	30.46	29.54	32.76	32.57
Industrial wastewater	N_2O	0.022	0.021	0.021	0.022	0.021	0.022	0.022	0.020	0.018	0.019	0.019
Year		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Domestic and commercial wastewater	CH_4	6.31	6.27	6.23	6.20	6.16	6.16	6.18	6.17	6.06	6.09	6.05
Human sewage	N_2O	0.98	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.94	0.95	0.94
Industrial wastewater	CH_4	31.70	32.27	32.53	32.75	34.83	37.1	38.31	40.21	39.55	42.01	41.94
Industrial wastewater	N_2O	0.019	0.020	0.020	0.020	0.022	0.023	0.024	0.024	0.024	0.026	0.026
Year		2023										
Domestic and commercial wastewater	CH_4	6.04										
Human sewage	N_2O	0.94										
Industrial wastewater	CH_4	42.05										
Industrial wastewater	N_2O	0.026										

7.5.2 Methodology

CH_4 and N_2O emissions from domestic wastewater handling and N_2O emissions from commercial wastewater handling were estimated according to the default methodologies suggested by IPCC. CH_4 emissions from commercial wastewater handling were estimated based on country specific data as well as on IPCC default values.

CH_4 emissions from domestic and commercial wastewater handling

It is estimated that about 91% of Greek population in 2023 was served by domestic wastewater treatment systems in compliance with the Directive 91/271/EEC (3rd Programming Period). These systems consist of a primary treated effluent and an advanced secondary biological treatment with activated sludge system for removing organic load and a significant reduction in nitrogen load. This process occurs in biological gradient, consisting of bioreactors and final sedimentation tanks, which precipitated the biological sludge. The final output is the sea with an undersea pipeline system deep diffusion. As it is mentioned in ***Chapter 7.2.2***, the final sludge is landfilled in the SWDS.

The remaining 9% of Greek population, mainly this in remote areas was not served by a wastewater treatment system and it is going to change during the 4th Programming period, thus, it is considered their wastewater discharges in sea, river etc. ***Table 7.24***, provides for the whole of period 1990-2023 data relevant to the share of population connected to the sewer systems in Greece, as per Ministry of Environment and Energy (MEEN).

Table 7.24 Share of population connected to the sewer systems (%)

Year	1960	1965	1970	1975	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
Share	5.0	7.2	10.3	14.8	16.7	18.7	21.1	24.3	28.1	5.0	7.2	10.3	14.8	16.7	18.7
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Share	32.4	47.6	70.0	74.4	79.1	84.1	86.8	88.8	90.2	90.4	90.8	90.9	91.0	91.0	91.0
Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023					
Share	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0	91.0					

Methane emissions from domestic and commercial wastewater handling are calculated using the following equations:

$$CH_4 \text{ emissions} = TOW \times EF - MR$$

$$TOW = P \times D_{dom}$$

$$EF = Bo \times MCFs$$

The parameters used are presented hereafter:

- **Total organic waste, *TOW***. The calculation of total organic waste is based on population data (*P*), as presented in ***Table 7.6***, and the degradable organic component D_{dom}, that is set equal to 0.057 kg BOD/person/day (2006 IPCC, Chap. 6, page 6.14, Table 6.4, suggested figure for Greece) following also Bilateral Review with experts from Spain recommendation.

Emission factor, *EF*. The emission factor is estimated considering the maximum methane production potential ***Bo*** and the weighted average of the methane conversion factors (***MCFs)***, for the different wastewater treatment systems used in the country. The value of 0.6 kg CH_4/kg BOD was used for the domestic wastewater handling while the value of 0.25 kg CH_4/kg COD was used for the industrial wastewater handling, as suggested by the IPCC Good Practice Guidance.

The MCF indicates the extent to which the methane producing potential (Bo) is realised in each type of treatment method. The proposed figure by TERT during 2016 European Union review is used, i.e. 0.5 for the share of wastewater from population not connected to the sewer system which treatment is considers that complies with this reported as "Septic system" in IPCC 2006 Table 6.3, and 0 for the share of wastewater from population connected to the sewer system).

- **Methane recovery *MR*** is considered to be equal to zero.

In ***Table 7.24*** the degradable organic waste (as kt BOD) for the period 1990 – 2023, is presented.

The calculation of BOD from sludge removed and disposed on land is based on the amounts of sludge transferred in the managed SWDS of Athens (***Table 7.25***) and the following parameters:

- Volume of biogas per unit of dry matter: 200 m^3/ tn dry matter. The factor results from the data provided by EYDAP.
- Methane density: 0.7 kg CH_4/ m3
- Fraction of methane in sludge biogas (F): 0.6

Biochemical oxygen demand (BOD) for sludge is finally subtracted from total BOD and methane emissions are calculated based on the fraction of BOD that degrades anaerobically. The relevant data are included in the reports of the Ministry of Environment and Energy (MEEN) on the implementation of EU Directive 91/71 regarding the collection, treatment and disposal of municipal wastewater.

Regarding biogas recovered during sludge treatment before its disposal, it must be noted that this corresponds to gas recovered in the municipal waste-water treatment plants during the anaerobic digestion before its disposal. During disposal of stabilized sludge no gas recover is performed, therefore, no gas reported in emissions from sludge disposal sector.

Table 7.25 ***BOD (in kt) from domestic and commercial wastewater, sludge and total for the period 1990 – 2023***

Year	Wastewater	Sludge	Total
1990	209.54	6.51	216.05
1991	212.47	6.51	218.98
1992	216.95	6.51	223.46
1993	221.47	6.51	227.98
1994	224.64	6.51	231.16
1995	226.96	6.98	233.93
1996	229.71	6.98	236.69
1997	232.01	8.24	240.25
1998	235.80	8.02	243.82
1999	239.43	8.13	247.55
2000	248.18	8.96	257.14
2001	261.44	9.16	270.59
2002	263.35	10.49	273.85
2003	266.56	10.78	277.34
2004	269.78	11.27	281.05
2005	268.17	15.78	283.96
2006	269.40	17.02	286.43
2007	270.61	18.10	288.72
2008	271.58	18.39	289.98
2009	270.79	20.47	291.27
2010	278.02	14.04	292.06
2011	275.63	12.25	287.89
2012	274.54	12.16	286.70
2013	269.78	15.28	285.05
2014	267.67	15.69	283.36
2015	266.49	15.31	281.80
2016	263.88	16.18	280.07
2017	265.27	14.93	280.20
2018	266.57	14.30	280.87
2019	266.76	13.67	280.43
2020	262.84	12.44	275.28
2021	263.52	13.31	276.84
2022	261.59	13.39	274.98
2023	260.88	13.69	274.57

N_2O emissions from domestic wastewater handling

N_2O emissions from domestic wastewater handling are estimated as the indirect nitrous oxide emissions from human consumption of food and their subsequent treatment through wastewater handling systems are estimated by the following equation:

$$N_2O \text{ emissions} = P \times Protein \times F_{NPR} \times F_{NON\text{-}CON} \times F_{IND\text{-}COM} \times EF\ (N_2O\text{-}N/N)$$

Data on protein consumption (*Protein*) are provided by FAO. The population (*P*) used, is the one presented in ***Table 7.6***, while the values of the parameters regarding the fraction of protein that is nitrogen (F_{NPR}) and the conversion of nitrogen to nitrous oxide [*EF* (N_2O-N/N)] are those suggested by the IPCC Guidelines.

$F_{NON\text{-}CON}$, factor for non-consumed protein added to the wastewater, is considered equal to 1.4, following IPCC 2006 Guidelines for developed countries.

Factor for industrial and commercial co-discharged protein into the sewer system ($F_{IND\text{-}COM}$) is considered equal to 1.25, following 2006 IPCC Guidelines, to include wastewater contain protein from industrial or commercial sources similar nature, that is discharged into the sewer and it may contain protein (e.g., from grocery stores and butchers). As it is described below, N_2O emissions from industrial sector produced during industrial production (e.g. in big food companies, Sugar industry e.t.c.) are calculated based on EMEP/CORINAIR, 2007 emission factor, equal to 0.25 g N_2O/m3 of wastewater production.

In ***Table 7.26*** the consumption of protein (kg/person/year) for the period 1990 – 2023, is presented.

Table 7.26 Annual protein consumption (in kg/person) for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Protein (kg/capita)	40.81	41.09	41.06	40.91	41.28	41.37	41.26	41.38	40.92	42.43	44.08
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Protein (kg/capita)	42.09	41.56	42.99	42.80	41.81	41.48	42.02	40.85	41.34	40.86	39.99
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Protein (kg/capita)	39.50	39.71	39.71	39.71	39.71	39.71	39.71	39.71	39.71	39.71	39.71
Year	2023										
Protein (kg/capita)	39.71										

CH_4 emissions from industrial wastewater handling

The methodology for calculating methane emissions from industrial wastewater is similar to the one used for domestic wastewater, as it was presented above. Relevant to MCF, the proposed figure by TERT during 2016 European Union review is used, i.e. 0.8, for the share of the industrial wastewater treated anaerobically, and 0 for these treated aerobically.

In order to estimate the total organic waste produced through anaerobic treatment, the following basic steps were followed:

- Collection of data (from the ELSTAT) regarding industrial production of approximately 25 industrial sectors / sub-sectors for the period 1990 – 2023.
- Calculation of wastewater generated, with the use of country specific factors, as collected by Greek industries, and default factors suggested by the IPCC Good Practice Guidance in case where country specific data were not collected per industrial sector (m^3 of wastewater/t product).
- Calculation of degradable organic fraction of waste, with the use of country specific factors, as collected by Greek industries, and default factors suggested by the IPCC Good Practice Guidance in case where country specific data were not collected (kg COD/m^3 wastewater) for each sector / sub-sector.
- The distribution between aerobic and anaerobic treatment of industrial wastewater for each industrial sector was estimated on the basis of data derived from a project financed by the former Ministry of Environment, Energy and Climate Change (MEECC) (2001b), now MEEN. The maximum methane production potential factors Bo and the methane conversion factors for aerobic and anaerobic treatment, which were used for the final estimation of methane emissions, are similar to those used for domestic wastewater handling.

In ***Table 7.27***, parameters utilized for emissions from industrial wastewater are presented as far wastewater generation and COD are concerned, with explanation of source of these parameters. In addition, information relevant to the total industrial production and the shares of the wastewater treated aerobically and anaerobically are included.

Figures utilized for the paper industry are expert judgements and they are based on the following facts:

1. Greece mainly imports paper pulp instead of producing paper from wood. Therefore, less water is required for the treatment of paper with lower COD values. Significantly higher figures provided by IPCC are referred to the water consumption and total COD for paper production concerning the total paper production procedure.
2. In Greece, there are no factories that feed directly from rivers or lakes, as is the case in other European countries. This obliges the Greek paper industry to restrict water use.'

An example of published works regarding this issue (in Greek) was provided in 2017 ERT during 2017 review, approved that m^3 wastewater/ tn of product is approximately 5-6 m^3/tn.

Regarding sugar industry the highest proposed figures provided by IPCC have been utilized based on experts' judgments. Based on limited available data, e.g. this provided in 2017 ERT (in Greek),

m^3 wastewater/ tn could approach the figure of 23 m^3/ tn. Similarly, for Vegetable Oil, figures in the proposed range by IPCC Guidelines have been utilized based on expert judgements.

Table 7.27 Parameters for the estimation of emissions from industrial wastewater for 2023

	Share treated anaerobically (%)	ktn of product	m^3 wastewater/ tn of product	kg COD/ m^3 wastewater (In)	Source
Alcohol Refining	0.0	51	24	11	IPCC 2006
Beer & Malt	26.78	414	6.3	2.9	IPCC 2006
Dairy Products	0.0	1182	7	2.7	IPCC 2006
Fish industry	6.7	14	18	2.5	IPCC 2006
Meat & Poultry	4	499	13	4.1	IPCC 2006
Organic Chemicals	0.0	207	67	3	IPCC 2006
Paints	0.0	189	10	5.5	IPCC 2000
Oil industry	0.0	29206	0.6	1	IPCC 2006
Plastics & Resins	0.0	164	0.6	3.7	IPCC 2006
Wine & Vinegar	0.0	219	23	1.5	IPCC 2006
Paper	0.0	82	6.4	2.5	CS
Vegetable Oil	2.9	560	5	1.2	CS
Fruits industry	4.2	919	20	5	IPCC 2006
Sugar industry	16.8	83	18	6	CS
Textiles	3.3	189	172	0.9	IPCC 2000
Soft Drinks	0.0	601	2	2	IPCC 2000
Starch Production	0.0	6	18	10	CS

In ***Table 7.28*** the degradable organic waste by each sector (as COD) for the period 1990 – 2023, is presented.

CH_4 emissions from sludge generated industrial wastewater handling

For the estimation of CH_4 emissions from sludge generated industrial wastewater handling is being used a methodology similar to the one used for the estimation of CH_4 emissions from industrial wastewater handling using the same country specific and default factors. Having estimated the degradable organic component from industrial wastewater handling treated anaerobically as described in the previous paragraph, the remaining part is considered as this treated aerobically.

The fraction of it removed as sludge is estimated based either on published data for some major Greek companies (see Vlyssides et al., 2004; Vlyssides et al., 2006; Vlyssides et al., 2007; Vlyssides et al., 2008) or on assumptions for the industrial sectors that there are not sufficient data. In general, it is considered the aerobically systems is composed of a primary treatment of wastewater (mainly a primary clarifier) and a secondary treatment, which is consisted of an aeration tank and a final clarifier. The fraction of total degradable organic component removed through the primary clarifier is considered equal to 30% for the industrial sectors for which there are no available data while the 50 % of the remaining is removed through the secondary clarifier.

Table 7.28 Total industrial wastewater in COD (in kt) for each industrial sector for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Food and beverage	136.05	122.25	131.30	138.75	152.72	141.40	146.13	128.93	153.03	138.87	161.43
Paper and pulp	4.31	4.11	4.11	3.08	2.81	3.07	2.85	2.45	2.73	2.68	3.01
Organic chemicals	0.34	0.30	0.36	0.87	0.82	0.86	0.89	0.92	0.67	0.41	0.38
Other	18.30	18.29	19.37	18.79	21.36	21.53	24.26	22.77	24.67	21.47	23.85
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Food and beverage	168.98	151.27	147.51	156.02	142.45	150.41	129.44	108.68	112.20	129.12	129.70
Paper and pulp	3.05	3.23	3.38	3.53	3.84	3.79	3.56	3.49	3.37	3.08	2.53
Organic chemicals	0.23	0.23	0.23	0.23	0.27	1.07	1.08	9.03	6.39	7.60	7.57
Other	24.11	23.96	25.61	24.42	26.28	28.10	29.75	27.27	22.07	20.08	19.17
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Food and beverage	122.55	118.19	117.09	120.43	127.39	131.92	133.99	139.39	140.56	148.63	150.96
Paper and pulp	2.17	2.22	1.74	1.33	1.33	0.93	1.05	1.02	0.94	1.14	1.26
Organic chemicals	11.06	17.55	18.94	17.06	18.80	25.48	27.73	32.55	29.09	27.68	25.56
Other	18.98	19.85	21.50	21.61	23.04	23.57	24.90	24.13	23.33	28.50	27.84
Year	**2023**										
Food and beverage	151.23										
Paper and pulp	1.24										
Organic chemicals	25.71										
Other	27.99										

Following 2017 ERT recommendation, in order to provide justification of assumptions provided above, the following References are reported:

- Vlyssides, G. A., Loizides, M., and Karlis, K. P., 2004 "Integrated strategic approach for reusing olive oil extraction by-products", Journal of Cleaner Production, 12(6), pp. 603-611.
- Vlyssides A., Barampouti E.M., Mai S., 2006 "Effect of recirculation of currant-finishing wastewater (CFW) on their energy utilization", Biomass and Waste to Energy Symposium, 29 November – 1 December 2006, Venice, Italy.

- Vlyssides A., Barampouti E.M., Mai S., 2007 "Energy utilization and recirculation of currantfinishing wastewater", Journal of Hazardous Materials, 145, pp. 506-510
- Vlyssides A., Karlis P., Barampouti E.M., Mai S., 2008 "Effect of recirculation of currant-finishing wastewater (CFW) on its composition", Bioresource Technology 99 (5), pp. 1481-1485.

As it is obtained by these publications, the fraction of total degradable organic component removed through the primary clarifier is about: 25% for wine industry, 25-45% for oil industry, 15-20% for fruit industry, 15-20% for milk industry and 45-50% for potatoes industry. Therefore, as a mean value for the non - studied industries experts provided the value of 30%. Similarly, for the secondary clarifier, experts provided the value of 50% based on their experience.

The maximum methane production potential (Bo) is equal to 0.25 kg CH4/kg COD, as suggested by the IPCC Good Practice Guidance while the methane recovery is considered to be equal to zero.

The degradable organic waste of industrial sludge (as COD) for the whole time series period 1990 – 2023 is presented in ***Table 7.29***.

Table 7.29 TOW (in COD kt) removed as sludge from industrial wastewater handling for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
COD (kt)	138.38	127.12	135.65	140.44	155.98	147.48	153.56	136.29	158.62	145.70	166.36
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
COD (kt)	172.94	157.04	156.18	163.40	153.41	161.73	145.87	133.31	129.46	144.32	144.41
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
COD (kt)	139.78	143.66	145.70	147.21	156.07	167.28	172.07	181.27	178.59	189.51	189.26
Year	2023										
COD (kt)	189.85										

N_2O emissions from industrial wastewater handling

N_2O emissions from industrial wastewater have been estimated on the basis of the emission factors equal to 0.25 g N_2O/m^3 of wastewater production (EMEP/CORINAIR, 2007). The waste water production is resulting from the model for the estimation of methane emissions from industrial waste water. The waste water production for the whole time series period 1990 – 2023 is presented in ***Table 7.30***.

Table 7.30 Waste water production from the industrial sector (1000000m^3) for the period 1990 – 2023

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Waste water	72.42	69.86	73.74	71.71	78.43	76.62	82.12	74.08	83.74	76.72	85.74
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Waste water	89.79	83.42	85.77	86.83	84.59	89.62	86.58	81.75	73.93	76.45	74.71
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Waste water	76.65	79.29	81.41	81.55	86.31	90.94	95.90	98.07	95.32	104.38	104.18
Year	2023										
Waste water	104.62										

7.5.3 Uncertainties and time-series consistency

The combined uncertainty of CH_4 emissions of wastewater handling sector is estimated by 42.43%. The uncertainty associated with activity data and the emission factor is 30%.

The combined uncertainty of N_2O emissions of wastewater handling sector is estimated by 42.43% for Domestic Wastewater Treatment and Discharge and 104.4%% for Industrial Wastewater Treatment and Discharge.

The results of uncertainty analysis are presented in Table 1.8. The detailed calculations of uncertainty are presented in Annex IV (Tables IV.1 – IV.3).

The time-series consistency of emissions is controlled by applying consistent methodologies and verified activity data inline with IPCC guidelines. In case of changes or refinements in methodologies and Efs based on country-specific data, time-series consistency is ensured by performing recalculations according to the IPCC good practice guidance.

7.5.4 Source-specific QA/QC and verification

Source-specific quality control is carried out based on the principles of inventory Quality Assurance / Quality Control (QA/QC) plan (National Systems under Article 5 Paragraph 1 of the Protocol as described in Decision 20/CP.7). The special procedures are followed in the wastewater sector are:

1. Cross checking information regarding wastewater generated per production unit and degradable organic fraction of waste factors received by different Greek Industries.

2. Comparison of information regarding wastewater factors with this for other countries.

3. Estimations were checked with several calculations tools with checking of emissions trends and sums deviations.

7.5.5 Recalculations

Updated activity data, for industrial wastewater sub-category, have been utilized for the estimation of CH_4 and N_2O emissions from wastewater handling for 2022.

The deviation of CH_4 and N_2O emissions from this category in the present submission compared to the emissions estimated in the previous submission and the impact on total emissions (excl LULUCF) of recalculations are presented in ***Table 7.31***.

Table 7.31 Recalculations of CH_4 and N_2O emissions from wastewater handling sector

Year	2022
CH_4	
Difference (eq. CO_2 kt)	-13
Impact (%)	1
N_2O	
Difference (eq. CO_2 kt)	-0.02
Impact (%)	0.001

7.5.6 Planned improvements

The treatment conditions of the industrial wastewater and the distribution of different wastewater treatment systems are expected to be examined further in order to improve more the methodology for the estimation of the emissions from industrial wastewater.

8. Recalculations and improvements

8.1 Explanations and justifications for recalculations

The recalculations made are driven by the results of the various review processes, QC checks and internal audits and the ERT reviews of the annual submissions of Greece by the nominated experts from the UNFCCC.

The reasons for recalculations made, can be classified as follows:

- ***Changes or refinements in methods***. A methodological change occurs when an inventory agency uses a different tier to estimate emissions from a source category (e.g. for key source categories) or when it moves from a tier described in the IPCC Guidelines to a national method. Methodological changes are often driven by the development of new and different data sets. A methodological refinement occurs when an inventory agency uses the same tier to estimate emissions but applies it using a different data source or a different level of aggregation.
- ***Inclusion of new sources***. A new source is defined as a source for which estimates (all or some gases) did not exist in previous inventories either due to lack of data or because it has just been identified.
- ***Allocation***. Changes in allocation of emissions to different sectors or sources/sub-sources.
- ***Correction of errors***. This case concerns errors during calculating emissions (e.g. transcript errors) or while filling in the required information in the CRF tables. Inconsistencies resolving is also included in this category.
- ***Updated activity data***.

8.2 Recalculations of GHG inventory

8.2.1 GHG inventory

The justification of the recalculations made in the present submission as far as the preparation of GHG inventory is concerned has been presented in details in Chapters 3 – 7.

8.3 Implications for emissions levels

8.3.1 GHG inventory

In ***Table 8.1*** the effect of the recalculations made on the total GHG emissions in Greece excluding LULUCF on a per gas basis is presented.

Table 8.1 Comparison of the 2024 and 2025 submissions (in Mt CO_2 eq)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
CO_2 emissions											
2024 submission	83.44	83.41	84.98	84.28	86.43	86.96	89.11	93.80	98.62	97.93	102.97
2025 submission	83.44	83.41	84.98	84.28	86.43	86.96	89.11	93.80	98.62	97.93	102.97
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 emissions											
2024 submission	12.53	12.51	12.59	12.64	12.71	12.91	13.09	13.04	13.28	13.24	13.24
2025 submission	12.53	12.51	12.59	12.64	12.71	12.91	13.09	13.04	13.28	13.24	13.24
Change (%)	0.0000	0.0000	0.0002	0.0000	0.0003	0.0001	0.0004	0.0000	-0.0002	0.0001	-0.0002
N_2O emissions											
2024 submission	6.86	6.74	6.59	6.10	5.97	6.16	6.31	6.17	6.09	6.05	5.87
2025 submission	6.86	6.74	6.59	6.10	5.97	6.16	6.31	6.17	6.09	6.05	5.87
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
F-gases emissions											
2024 submission	1.17	1.35	1.13	1.81	2.34	3.55	4.10	4.46	5.00	5.77	4.57
2025 submission	1.17	1.35	1.13	1.81	2.34	3.55	4.10	4.46	5.00	5.77	4.57
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total emissions											
2024 submission	103.986	104.006	105.288	104.828	107.458	109.581	112.616	117.470	122.994	122.986	126.659
2025 submission	103.986	104.006	105.288	104.828	107.458	109.581	112.616	117.470	122.994	122.986	126.659
Change (%)	0.00000	0.00001	0.00003	0.00001	0.00004	0.00002	0.00004	-0.00002	-0.00002	0.00001	-0.00001

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CO_2 emissions											
2024 submission	105.36	105.00	109.07	109.49	113.89	112.42	114.55	111.08	104.32	97.35	94.51
2025 submission	105.36	105.00	109.07	109.49	113.89	112.42	114.55	111.08	104.32	97.35	94.51
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
CH_4 emissions											
2024 submission	12.47	12.57	12.68	12.71	12.80	12.88	12.78	12.64	12.25	12.51	12.34
2025 submission	12.47	12.57	12.68	12.71	12.80	12.88	12.78	12.64	12.25	12.51	12.34
Change (%)	-0.0006	0.0004	0.0007	0.0001	-0.0006	-0.0009	0.0010	-0.0010	0.0000	0.0004	0.0001
N_2O emissions											
2024 submission	5.74	5.69	5.62	5.63	5.47	5.31	5.40	5.18	4.86	5.04	4.82
2025 submission	5.74	5.69	5.62	5.63	5.47	5.31	5.40	5.18	4.86	5.04	4.82
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2024 submission	4.16	4.46	4.20	4.39	4.59	2.66	3.16	3.61	3.89	4.34	4.59
2025 submission	4.16	4.46	4.20	4.39	4.59	2.66	3.16	3.61	3.89	4.34	4.59
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total emissions											
2024 submission	127.731	127.719	131.569	132.215	136.748	133.270	135.883	132.519	125.326	119.234	116.257
2025 submission	127.731	127.719	131.569	132.215	136.748	133.270	135.883	132.519	125.326	119.234	116.257
Change (%)	-0.00005	0.00004	0.00006	0.00000	-0.00007	-0.00008	0.00009	-0.00011	0.00000	0.00003	0.00001

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2 emissions											
2024 submission	91.39	81.71	78.64	74.93	71.36	74.84	71.78	65.74	55.56	57.52	58.08
2025 submission	91.39	81.71	78.64	74.93	71.36	74.84	71.78	65.74	55.58	57.53	57.69
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0338	0.0151	-0.6775
CH_4 emissions											
2024 submission	12.17	11.90	11.70	11.49	11.11	11.46	11.62	11.39	11.38	11.75	11.81
2025 submission	12.17	11.90	11.70	11.49	11.11	11.46	11.62	11.39	11.38	11.75	11.77
Change (%)	-0.0006	-0.0001	-0.0001	0.0002	-0.0004	0.0010	-0.0011	-0.0009	-0.0008	0.0067	-0.3228
N_2O emissions											
2024 submission	4.44	4.17	3.97	3.90	3.95	4.02	3.92	3.91	3.96	3.94	3.73
2025 submission	4.44	4.17	3.97	3.90	3.95	4.02	3.92	3.91	3.96	3.94	3.74
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0004	0.0003	0.1655
2024 submission	5.00	5.56	5.63	5.75	5.97	5.93	5.69	5.27	4.95	4.79	4.65
2025 submission	5.00	5.56	5.63	5.75	5.97	5.93	5.69	5.27	4.95	4.79	4.65
Change (%)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0247
Total emissions											
2024 submission	113.008	103.354	99.937	96.073	92.398	96.246	93.011	86.306	75.855	78.004	78.271
2025 submission	113.008	103.354	99.937	96.073	92.398	96.246	93.011	86.306	75.874	78.013	77.847
Change (%)	-0.00006	-0.00001	-0.00001	0.00003	-0.00004	0.00013	-0.00016	-0.00006	0.02462	0.01219	-0.54202

8.4 Implications for emissions trends

8.4.1 GHG inventory

The emission trends in Greece for the period 1990 – 2022 according to the inventories submitted in 2024 & 2025 are shown in ***Figure 8.1***. As it shown, emission trends for the period 2000-2019 are hardly the same with 2023 submission while for 2020, 2021 and 2022 bigger differences are shown due to updated activity data utilized in several sectors (Refer to Chapters 3 to 7 for Details).

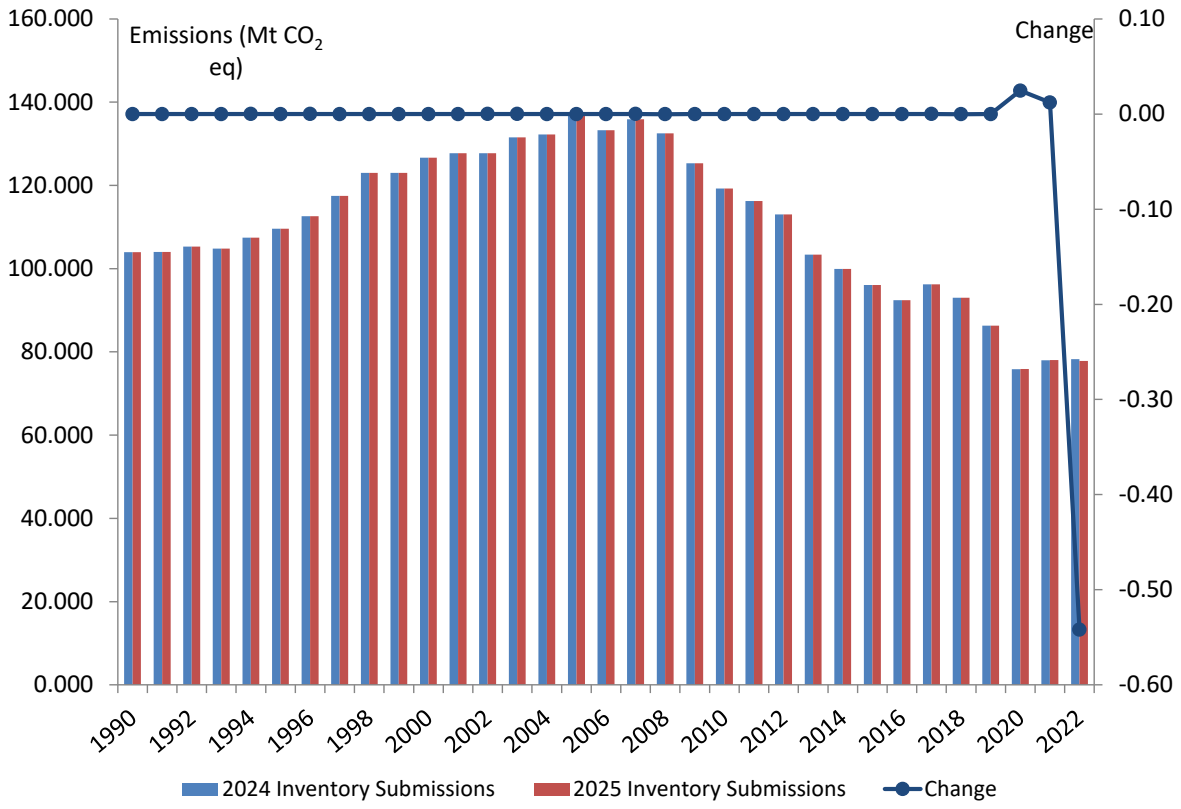


Figure 8.1 ***GHG emissions trends in Greece for the period 1990 – 2022 (without LULUCF) according to the inventories submitted in 2024 & 2025***

8.5 Recalculations, including in response to the review process, and planned improvements

An inventory improvement procedure is in place, which utilizes:

a) the recommendations from UNFCCC ERT reports,

b) the annual QA/QC checks of the inventory by EU under the Monitoring Mechanism Regulation (MMR),

c) the recommendations of 2016 comprehensive review of national greenhouse gas inventory data pursuant to Article 19(1) of Regulation (EU) No 525 (MMR),

c) the findings of independent audits carried out by local experts at the end of each year,

d) the findings of annual internal audits taken place by MEEN personnel in February and March of each year,

e) the output of key category analysis, uncertainty analysis and QA/QC procedures,

f) the recommendations / proposals arose in the framework of bilateral QA exercise with other inventory teams (e.g. the bilateral QA exercise between the Spanish and the Greek Inventory team that took place in October of 2013).

As a basis to prioritize, plan and materialize future improvements and recalculations. As mentioned above, details on the resulted recalculations and improvements planned per source/sink category have been presented in the respective chapters (Chapters 3 – 7).

Finally, it should be mentioned that the results and the proposals that will arise from the review of the present inventory, within the technical review process defined in relevant decisions of the Conference of the Parties, will be integrated in the plan for the improvement of the GHG emissions inventory.

No major changes in methodological descriptions performed in current NIR compared to previous year NIR have implemented.

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ANNEXES

Annex I: Key categories

The 2006 IPCC Guidelines defines procedures (in the form of decision trees) for the choice of estimation methods within the context of the IPCC Guidelines. Decision trees formalize the choice of the estimation method most suited to national circumstances considering at the same time the need for accuracy and the available resources (both financial and human). Generally. inventory uncertainty is lower when emissions are estimated using the most rigorous methods. but due to finite resources. this may not be feasible for every source category. Therefore. it is good practice to identify those source categories (key source categories) that have the greatest contribution to overall inventory uncertainty in order to make the most efficient use of available resources.

In that context. a "key source category" is one that is prioritised within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions (level assessment) or/and to the trend of emissions (trend assessment).

As far as possible. key source categories should receive special consideration in terms of two important inventory aspects.

4. The use of source category-specific good practice methods is preferable. unless resources are unavailable.
5. The key source categories should receive additional attention with respect to quality assurance (QA) and quality control (QC).

The determination of the key categories without *LULUCF* for the Greek inventory system is based on the application of the Tier 1 methodology described in the 2006 IPCC GLs (***Tables I.1. I.3*** and ***I.5***). adopting the categorization of sources that is presented in the GLs. Key categories are those which. when summed together in descending order of magnitude. add up to over 95% of total emissions (level assessment) or the trend of the inventory in absolute terms. It should be noted that. according to the 2006 IPCC GLs the trend is estimated on the basis of the base year (1990). The methodology for the determination of key categories with *LULUCF* is in fact the same as for the one for key sources without LULUCF (***Tables I.2. I.4 and I.6***).

The key categories analysis has been performed for the total of the time series (years 1990-2023) on both level and trend analysis basis. Any differences between the key categories in the time-series are due to the flunctuation of the trend in specific categories and refer to trend analysis.

Table I.1 Key categories analysis with LULUCF – Level assessment for 2023

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	X
1.A.3.a	Domestic Aviation	CO2	X
1.A.3.b	Road Transportation	CO2	X
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Gaseous Fuels	CO2	X
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO2	X
2.A.1	Cement Production	CO2	
2.B.10	Other	CO2	X
2.C.3	Aluminium Production	CO2	X
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	X
3.A	Enteric Fermentation	CH4	X
3.B	Manure Management	CH4	X
3.B	Manure Management	N2O	
3.D.1	Direct N2O Emissions From Managed Soils	N2O	X
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	X
4.A.1	Forest Land Remaining Forest Land	CO2	X
4.B.1	Cropland Remaining Cropland	CO2	X
4.C.2	Land Converted to Grassland	CO2	X
4(IV)	Biomass Burning	CH4	X
5.A	Solid Waste Disposal	CH4	X
5.D	Wastewater Treatment and Discharge	CH4	X
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CO2	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Peat	CO2	
1.A.1	Fuel combustion - Energy Industries - Peat	CH4	
1.A.1	Fuel combustion - Energy Industries - Peat	N2O	
1.A.1	Fuel combustion - Energy Industries - Biomass	CH4	
1.A.1	Fuel combustion - Energy Industries - Biomass	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	N2O	
1.A.3.a	Domestic Aviation	CH4	
1.A.3.a	Domestic Aviation	N2O	
1.A.3.b	Road Transportation	CH4	
1.A.3.b	Road Transportation	N2O	
1.A.3.c	Railways	CO2	
1.A.3.c	Railways	CH4	
1.A.3.c	Railways	N2O	
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CO2	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CH4	
1.A.3.d	Domestic Navigation - Gaseous Fuels	N2O	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CO2	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CH4	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	N2O	
1.A.3.d	Domestic Navigation - Biomass Fuels	CH4	
1.A.3.d	Domestic Navigation - Biomass Fuels	N2O	
1.A.3.e	Other Transportation	CO2	
1.A.3.e	Other Transportation	CH4	
1.A.3.e	Other Transportation	N2O	
1.A.4	Other Sectors - Liquid Fuels	CH4	
1.A.4	Other Sectors - Liquid Fuels	N2O	
1.A.4	Other Sectors - Solid Fuels	CO2	
1.A.4	Other Sectors - Solid Fuels	CH4	
1.A.4	Other Sectors - Solid Fuels	N2O	
1.A.4	Other Sectors - Gaseous Fuels	CH4	
1.A.4	Other Sectors - Gaseous Fuels	N2O	
1.A.4	Other Sectors - Other Fossil Fuels	CO2	
1.A.4	Other Sectors - Other Fossil Fuels	CH4	
1.A.4	Other Sectors - Other Fossil Fuels	N2O	
1.A.4	Other Sectors - Peat	CO2	
1.A.4	Other Sectors - Peat	CH4	
1.A.4	Other Sectors - Peat	N2O	
1.A.4	Other Sectors - Biomass	CH4	
1.A.4	Other Sectors - Biomass	N2O	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Peat	CO2	
1.A.5	Other (Not specified elsewhere) - Peat	CH4	
1.A.5	Other (Not specified elsewhere) - Peat	N2O	
1.A.5	Other (Not specified elsewhere) - Biomass	CH4	
1.A.5	Other (Not specified elsewhere) - Biomass	N2O	
1.B.1	Fugitive emissions from Solid Fuels	CO2	
1.B.1	Fugitive emissions from Solid Fuels	CH4	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH4	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO2	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CO2	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	N2O	
1.B.2.d	Fugitive Emissions from Fuels - Other	CO2	
1.B.2.d	Fugitive Emissions from Fuels - Other	CH4	
1.B.2.d	Fugitive Emissions from Fuels - Other	N2O	
1.C	CO2 Transport and Storage	CO2	
1.	Energy (indirect CO2 emissions)	CO2	
2.A.2	Lime Production	CO2	
2.A.3	Glass Production	CO2	
2.A.4	Other Process Uses of Carbonates	CO2	
2.B.1	Ammonia Production	CO2	
2.B.1	Ammonia Production	CH4	
2.B.1	Ammonia Production	N2O	
2.B.2	Nitric Acid Production	N2O	
2.B.3	Adipic Acid Production	CO2	
2.B.3	Adipic Acid Production	N2O	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	CO2	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	
2.B.5	Carbide Production	CO2	
2.B.5	Carbide Production	CH4	
2.B.6	Titanium Dioxide Production	CO2	
2.B.7	Soda Ash Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CH4	
2.B.9	Fluorochemical Production	Aggregate F-gases	
2.B.10	Other	CH4	
2.B.10	Other	N2O	
2.B.10	Other	Aggregate F-gases	
2.C.1	Iron and Steel Production	CO2	
2.C.1	Iron and Steel Production	CH4	
2.C.2	Ferroalloys Production	CO2	
2.C.2	Ferroalloys Production	CH4	
2.C.3	Aluminium Production	PFCs	
2.C.3	Aluminium Production	SF6	
2.C.4	Magnesium Production	CO2	
2.C.4	Magnesium Production	HFCs	
2.C.4	Magnesium Production	PFCs	
2.C.4	Magnesium Production	SF6	

IPCC Category code	IPCC source categories	GHG	Level Assessment
2.C.4	Magnesium Production	Unspecified mix of HFCs and PFCs	
2.C.5	Lead Production	CO2	
2.C.6	Zinc Production	CO2	
2.C.7	Other	CO2	
2.C.7	Other	CH4	
2.C.7	Other	N2O	
2.C.7	Other	Aggregate F-gases	
2.D	Non-energy Products from Fuels and Solvent Use	CO2	
2.D	Non-energy Products from Fuels and Solvent Use	CH4	
2.D	Non-energy Products from Fuels and Solvent Use	N2O	
2.E	Electronics Industry	N2O	
2.E	Electronics Industry	Aggregate F-gases	
2.F.2	Foam Blowing Agents	Aggregate F-gases	
2.F.3	Fire Protection	Aggregate F-gases	
2.F.4	Aerosols	Aggregate F-gases	
2.F.5	Solvents	Aggregate F-gases	
2.F.6	Other Applications	Aggregate F-gases	
2.G	Other Product Manufacture and Use	CO2	
2.G	Other Product Manufacture and Use	CH4	
2.G	Other Product Manufacture and Use	N2O	
2.G	Other Product Manufacture and Use	Aggregate F-gases	
2.H	Other	CO2	
2.H	Other	CH4	X
2.H	Other	N2O	
2.H	Other	Aggregate F-gases	
2.	Industrial Proccesses and Produc Use (indirect CO2 emissions)	CO2	
3.C	Rice Cultivation	CH4	
3.D	Agricultural Soils	CH4	
3.E	Prescribed burning of savannas	CH4	
3.E	Prescribed burning of savannas	N2O	
3.F	Field burning of agricultural residues	CH4	
3.F	Field burning of agricultural residues	N2O	
3.G	Liming	CO2	
3.H	Urea Application	CO2	
3.I.	Other carbon-containing fertlizers	CO2	
3.J.	Other	CO2	
3.J.	Other	CH4	
3.J.	Other	N2O	
3.	Agriculture (indirect CO2 emissions)	CO2	
4.A.2	Land Converted to Forest Land	CO2	
4.B.2	Land Converted to Cropland	CO2	
4.C.1	Grassland Remaining Grassland	CO2	
4.D.1.1	Peat Extraction Remaining Peat Extraction	CO2	
4.D.1.2	Flooded Land Remaining Flooded Land	CO2	
4.D.1.3	Other Wetlands Remaining Other Wetlands	CO2	

IPCC Category code	IPCC source categories	GHG	Level Assessment
4.D.2	Land Converted to Wetlands	CO2	
4.E.1	Settlements Remaining Settlements	CO2	
4.E.2	Land Converted to Settlements	CO2	
4.F.1	Other Land Remaining Other Land	CO2	
4.F.2	Land Converted to Other Land	CO2	
4.G	Harvested Wood Products	CO2	
4(I).	Direct and indirect N2O emissions from N inputs to managed soils	N2O	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH4	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	N2O	
4(III).Direct	and indirect N2O emissions from N mineralization/immobilization	N2O	
4(IV)	Biomass Burning	CO2	
4(IV)	Biomass Burning	N2O	
4.H	Other	CO2	
4.H	Other	CH4	
4.H	Other	N2O	
4.	LULUCF (indirect CO2 emissions)	CO2	
5.B	Biological Treatment of Solid Waste	CH4	
5.B	Biological Treatment of Solid Waste	N2O	
5.C	Incineration and Open Burning of Waste	CO2	
5.C	Incineration and Open Burning of Waste	CH4	
5.C	Incineration and Open Burning of Waste	N2O	
5.D	Wastewater Treatment and Discharge	N2O	
5.E	Other	CO2	
5.E	Other	CH4	
5.E	Other	N2O	
5.	Waste (indirect CO2 emissions)	CO2	
6.	Other	CO2	
6.	Other	CH4	
6.	Other	N2O	
6.	Other	Aggregate F-gases	
6.	Other (indirect CO2 emissions)	CO2	

Table I.2 Key categories analysis without LULUCF – Level assessment for 2023

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	X
1.A.3.a	Domestic Aviation	CO2	X
1.A.3.b	Road Transportation	CO2	X
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Gaseous Fuels	CO2	X
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO2	X
2.A.1	Cement Production	CO2	X
2.B.10	Other	CO2	X
2.C.3	Aluminium Production	CO2	X
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	X
3.A	Enteric Fermentation	CH4	X
3.B	Manure Management	CH4	X
3.B	Manure Management	N2O	X
3.D.1	Direct N2O Emissions From Managed Soils	N2O	X
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	X
5.A	Solid Waste Disposal	CH4	X
5.D	Wastewater Treatment and Discharge	CH4	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	
1.B.1	Fugitive emissions from Solid Fuels	CH4	
2.B.1	Ammonia Production	CO2	
2.B.2	Nitric Acid Production	N2O	
4.A.1	Forest Land Remaining Forest Land	CO2	
4.B.1	Cropland Remaining Cropland	CO2	
4.C.2	Land Converted to Grassland	CO2	
4(IV)	Biomass Burning	CH4	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CO2	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Peat	CO2	
1.A.1	Fuel combustion - Energy Industries - Peat	CH4	
1.A.1	Fuel combustion - Energy Industries - Peat	N2O	
1.A.1	Fuel combustion - Energy Industries - Biomass	CH4	
1.A.1	Fuel combustion - Energy Industries - Biomass	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid	CH4	

IPCC Category code	IPCC source categories	GHG	Level Assessment
	Fuels		
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	N2O	
1.A.3.a	Domestic Aviation	CH4	
1.A.3.a	Domestic Aviation	N2O	
1.A.3.b	Road Transportation	CH4	
1.A.3.b	Road Transportation	N2O	
1.A.3.c	Railways	CO2	
1.A.3.c	Railways	CH4	
1.A.3.c	Railways	N2O	
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CO2	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CH4	
1.A.3.d	Domestic Navigation - Gaseous Fuels	N2O	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CO2	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CH4	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	N2O	
1.A.3.d	Domestic Navigation - Biomass Fuels	CH4	
1.A.3.d	Domestic Navigation - Biomass Fuels	N2O	
1.A.3.e	Other Transportation	CO2	
1.A.3.e	Other Transportation	CH4	
1.A.3.e	Other Transportation	N2O	
1.A.4	Other Sectors - Liquid Fuels	CH4	
1.A.4	Other Sectors - Liquid Fuels	N2O	
1.A.4	Other Sectors - Solid Fuels	CO2	
1.A.4	Other Sectors - Solid Fuels	CH4	
1.A.4	Other Sectors - Solid Fuels	N2O	
1.A.4	Other Sectors - Gaseous Fuels	CH4	
1.A.4	Other Sectors - Gaseous Fuels	N2O	
1.A.4	Other Sectors - Other Fossil Fuels	CO2	
1.A.4	Other Sectors - Other Fossil Fuels	CH4	
1.A.4	Other Sectors - Other Fossil Fuels	N2O	
1.A.4	Other Sectors - Peat	CO2	
1.A.4	Other Sectors - Peat	CH4	
1.A.4	Other Sectors - Peat	N2O	
1.A.4	Other Sectors - Biomass	CH4	
1.A.4	Other Sectors - Biomass	N2O	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Peat	CO2	
1.A.5	Other (Not specified elsewhere) - Peat	CH4	
1.A.5	Other (Not specified elsewhere) - Peat	N2O	
1.A.5	Other (Not specified elsewhere) - Biomass	CH4	
1.A.5	Other (Not specified elsewhere) - Biomass	N2O	
1.B.1	Fugitive emissions from Solid Fuels	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH4	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO2	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CO2	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	N2O	
1.B.2.d	Fugitive Emissions from Fuels - Other	CO2	
1.B.2.d	Fugitive Emissions from Fuels - Other	CH4	
1.B.2.d	Fugitive Emissions from Fuels - Other	N2O	
1.C	CO2 Transport and Storage	CO2	
1.	Energy (indirect CO2 emissions)	CO2	
2.A.2	Lime Production	CO2	
2.A.3	Glass Production	CO2	
2.A.4	Other Process Uses of Carbonates	CO2	
2.B.1	Ammonia Production	CH4	
2.B.1	Ammonia Production	N2O	
2.B.3	Adipic Acid Production	CO2	
2.B.3	Adipic Acid Production	N2O	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	CO2	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	
2.B.5	Carbide Production	CO2	
2.B.5	Carbide Production	CH4	
2.B.6	Titanium Dioxide Production	CO2	
2.B.7	Soda Ash Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CH4	
2.B.9	Fluorochemical Production	Aggregate F-gases	
2.B.10	Other	CH4	
2.B.10	Other	N2O	
2.B.10	Other	Aggregate F-gases	
2.C.1	Iron and Steel Production	CO2	
2.C.1	Iron and Steel Production	CH4	
2.C.2	Ferroalloys Production	CO2	
2.C.2	Ferroalloys Production	CH4	
2.C.3	Aluminium Production	PFCs	
2.C.3	Aluminium Production	SF6	
2.C.4	Magnesium Production	CO2	

IPCC Category code	IPCC source categories	GHG	Level Assessment
2.C.4	Magnesium Production	HFCs	
2.C.4	Magnesium Production	PFCs	
2.C.4	Magnesium Production	SF6	
2.C.4	Magnesium Production	Unspecified mix of HFCs and PFCs	
2.C.5	Lead Production	CO2	
2.C.6	Zinc Production	CO2	
2.C.7	Other	CO2	
2.C.7	Other	CH4	
2.C.7	Other	N2O	
2.C.7	Other	Aggregate F-gases	
2.D	Non-energy Products from Fuels and Solvent Use	CO2	
2.D	Non-energy Products from Fuels and Solvent Use	CH4	
2.D	Non-energy Products from Fuels and Solvent Use	N2O	
2.E	Electronics Industry	N2O	
2.E	Electronics Industry	Aggregate F-gases	
2.F.2	Foam Blowing Agents	Aggregate F-gases	
2.F.3	Fire Protection	Aggregate F-gases	
2.F.4	Aerosols	Aggregate F-gases	
2.F.5	Solvents	Aggregate F-gases	
2.F.6	Other Applications	Aggregate F-gases	
2.G	Other Product Manufacture and Use	CO2	
2.G	Other Product Manufacture and Use	CH4	
2.G	Other Product Manufacture and Use	N2O	
2.G	Other Product Manufacture and Use	Aggregate F-gases	
2.H	Other	CO2	
2.H	Other	CH4	
2.H	Other	N2O	
2.H	Other	Aggregate F-gases	
2.	Industrial Proccesses and Produc Use (indirect CO2 emissions)	CO2	
3.C	Rice Cultivation	CH4	
3.D	Agricultural Soils	CH4	
3.E	Prescribed burning of savannas	CH4	
3.E	Prescribed burning of savannas	N2O	
3.F	Field burning of agricultural residues	CH4	
3.F	Field burning of agricultural residues	N2O	
3.G	Liming	CO2	
3.H	Urea Application	CO2	
3.I.	Other carbon-containing fertlizers	CO2	
3.J.	Other	CO2	
3.J.	Other	CH4	
3.J.	Other	N2O	
3.	Agriculture (indirect CO2 emissions)	CO2	
4.A.2	Land Converted to Forest Land	CO2	
4.B.2	Land Converted to Cropland	CO2	
4.C.1	Grassland Remaining Grassland	CO2	
4.D.1.1	Peat Extraction Remaining Peat Extraction	CO2	

IPCC Category code	IPCC source categories	GHG	Level Assessment
4.D.1.2	Flooded Land Remaining Flooded Land	CO2	
4.D.1.3	Other Wetlands Remaining Other Wetlands	CO2	
4.D.2	Land Converted to Wetlands	CO2	
4.E.1	Settlements Remaining Settlements	CO2	
4.E.2	Land Converted to Settlements	CO2	
4.F.1	Other Land Remaining Other Land	CO2	
4.F.2	Land Converted to Other Land	CO2	
4.G	Harvested Wood Products	CO2	
4(I).	Direct and indirect N2O emissions from N inputs to managed soils	N2O	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH4	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	N2O	
4(III).Direct	and indirect N2O emissions from N mineralization/immobilization	N2O	
4(IV)	Biomass Burning	CO2	
4(IV)	Biomass Burning	N2O	
4.H	Other	CO2	
4.H	Other	CH4	
4.H	Other	N2O	
4.	LULUCF (indirect CO2 emissions)	CO2	
5.B	Biological Treatment of Solid Waste	CH4	
5.B	Biological Treatment of Solid Waste	N2O	
5.C	Incineration and Open Burning of Waste	CO2	
5.C	Incineration and Open Burning of Waste	CH4	
5.C	Incineration and Open Burning of Waste	N2O	
5.D	Wastewater Treatment and Discharge	N2O	
5.E	Other	CO2	
5.E	Other	CH4	
5.E	Other	N2O	
5.	Waste (indirect CO2 emissions)	CO2	
6.	Other	CO2	
6.	Other	CH4	
6.	Other	N2O	
6.	Other	Aggregate F-gases	
6.	Other (indirect CO2 emissions)	CO2	

Table I.3 Key categories analysis with LULUCF – Level assessment for 1990

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	X
1.A.3.b	Road Transportation	CO2	X
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Liquid Fuels	CO2	X
1.B.1	Fugitive emissions from Solid Fuels	CH4	X
2.A.1	Cement Production	CO2	X
2.B.1	Ammonia Production	CO2	X
2.B.2	Nitric Acid Production	N2O	X
2.B.9	Fluorochemical Production	Aggregate F-gases	X
2.C.2	Ferroalloys Production	CO2	X
3.A	Enteric Fermentation	CH4	X
3.B	Manure Management	CH4	X
3.D.1	Direct N2O Emissions From Managed Soils	N2O	X
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	X
4.A.1	Forest Land Remaining Forest Land	CO2	X
4.B.1	Cropland Remaining Cropland	CO2	X
5.A	Solid Waste Disposal	CH4	X
5.D	Wastewater Treatment and Discharge	CH4	X
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CO2	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Peat	CO2	
1.A.1	Fuel combustion - Energy Industries - Peat	CH4	
1.A.1	Fuel combustion - Energy Industries - Peat	N2O	
1.A.1	Fuel combustion - Energy Industries - Biomass	CH4	
1.A.1	Fuel combustion - Energy Industries - Biomass	N2O	
1.A.1	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2	

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	N2O	
1.A.2	Domestic Aviation	CH4	
1.A.3.a	Domestic Aviation	N2O	
1.A.3.a	Road Transportation	CH4	
1.A.3.a	Road Transportation	N2O	
1.A.3.b	Railways	CO2	
1.A.3.b	Railways	CH4	
1.A.3.c	Railways	N2O	
1.A.3.c	Domestic Navigation - Liquid Fuels	CH4	
1.A.3.c	Domestic Navigation - Liquid Fuels	N2O	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CO2	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CH4	
1.A.3.d	Domestic Navigation - Gaseous Fuels	N2O	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CO2	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CH4	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	N2O	
1.A.3.d	Domestic Navigation - Biomass Fuels	CH4	
1.A.3.d	Domestic Navigation - Biomass Fuels	N2O	
1.A.3.d	Other Transportation	CO2	
1.A.3.d	Other Transportation	CH4	
1.A.3.e	Other Transportation	N2O	
1.A.3.e	Other Sectors - Liquid Fuels	CH4	
1.A.3.e	Other Sectors - Liquid Fuels	N2O	
1.A.4	Other Sectors - Solid Fuels	CO2	
1.A.4	Other Sectors - Solid Fuels	CH4	
1.A.4	Other Sectors - Solid Fuels	N2O	
1.A.4	Other Sectors - Gaseous Fuels	CH4	
1.A.4	Other Sectors - Gaseous Fuels	N2O	
1.A.4	Other Sectors - Other Fossil Fuels	CO2	
1.A.4	Other Sectors - Other Fossil Fuels	CH4	
1.A.4	Other Sectors - Other Fossil Fuels	N2O	
1.A.4	Other Sectors - Peat	CO2	
1.A.4	Other Sectors - Peat	CH4	
1.A.4	Other Sectors - Peat	N2O	
1.A.4	Other Sectors - Biomass	CH4	
1.A.4	Other Sectors - Biomass	N2O	
1.A.4	Other (Not specified elsewhere) - Liquid Fuels	CH4	
1.A.4	Other (Not specified elsewhere) - Liquid Fuels	N2O	
1.A.4	Other (Not specified elsewhere) - Solid Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	N2O	

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.5	Other (Not specified elsewhere) - Peat	CO2	
1.A.5	Other (Not specified elsewhere) - Peat	CH4	
1.A.5	Other (Not specified elsewhere) - Peat	N2O	
1.A.5	Other (Not specified elsewhere) - Biomass	CH4	
1.A.5	Other (Not specified elsewhere) - Biomass	N2O	
1.A.5	Fugitive emissions from Solid Fuels	CO2	
1.A.5	Fugitive emissions from Solid Fuels	CH4	
1.A.5	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO2	
1.A.5	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH4	
1.B.1	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	
1.B.2.a	Fugitive Emissions from Fuels - Venting and flaring	CO2	
1.B.2.b	Fugitive Emissions from Fuels - Venting and flaring	CH4	
1.B.2.b	Fugitive Emissions from Fuels - Venting and flaring	N2O	
1.B.2.c	Fugitive Emissions from Fuels - Other	CO2	
1.B.2.c	Fugitive Emissions from Fuels - Other	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Other	N2O	
1.B.2.d	CO2 Transport and Storage	CO2	
1.B.2.d	Energy (indirect CO2 emissions)	CO2	
1.B.2.d	Lime Production	CO2	
1.C	Glass Production	CO2	
2.A.2	Other Process Uses of Carbonates	CO2	
2.A.3	Ammonia Production	CO2	
2.A.4	Ammonia Production	CH4	
2.B.1	Ammonia Production	N2O	
2.B.1	Nitric Acid Production	N2O	
2.B.3	Adipic Acid Production	CO2	
2.B.3	Adipic Acid Production	N2O	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	CO2	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	
2.B.5	Carbide Production	CO2	
2.B.5	Carbide Production	CH4	
2.B.6	Titanium Dioxide Production	CO2	
2.B.7	Soda Ash Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CH4	
2.B.10	Fluorochemical Production	Aggregate F-gases	
2.B.10	Other	CH4	
2.B.10	Other	N2O	
2.B.10	Other	Aggregate F-gases	
2.C.1	Iron and Steel Production	CO2	
2.C.1	Iron and Steel Production	CH4	
2.C.2	Ferroalloys Production	CO2	
2.C.3	Ferroalloys Production	CH4	
2.C.3	Aluminium Production	PFCs	
2.C.3	Aluminium Production	SF6	
2.C.4	Magnesium Production	CO2	
2.C.4	Magnesium Production	HFCs	
2.C.4	Magnesium Production	PFCs	
2.C.4	Magnesium Production	SF6	
2.C.4	Magnesium Production	Unspecified mix of HFCs and PFCs	

IPCC Category code	IPCC source categories	GHG	Level Assessment
2.C.5	Lead Production	CO2	
2.C.6	Zinc Production	CO2	
2.C.7	Other	CO2	
2.C.7	Other	CH4	
2.C.7	Other	N2O	
2.C.7	Other	Aggregate F-gases	
2.D	Non-energy Products from Fuels and Solvent Use	CO2	
2.D	Non-energy Products from Fuels and Solvent Use	CH4	
2.D	Non-energy Products from Fuels and Solvent Use	N2O	
2.E	Electronics Industry	N2O	
2.F.1	Electronics Industry	Aggregate F-gases	
2.F.2	Foam Blowing Agents	Aggregate F-gases	
2.F.3	Fire Protection	Aggregate F-gases	
2.F.4	Aerosols	Aggregate F-gases	
2.F.5	Solvents	Aggregate F-gases	
2.F.6	Other Applications	Aggregate F-gases	
2.G	Other Product Manufacture and Use	CO2	
2.G	Other Product Manufacture and Use	CH4	
2.G	Other Product Manufacture and Use	N2O	
2.G	Other Product Manufacture and Use	Aggregate F-gases	
2.H	Other	CO2	
2.H	Other	CH4	
2.H	Other	N2O	
2.H	Other	Aggregate F-gases	
3.B	Industrial Proccesses and Produc Use (indirect CO2 emissions)	CO2	
3.C	Rice Cultivation	CH4	
3.D	Agricultural Soils	CH4	
3.E	Prescribed burning of savannas	CH4	
3.E	Prescribed burning of savannas	N2O	
3.F	Field burning of agricultural residues	CH4	
3.F	Field burning of agricultural residues	N2O	
3.G	Liming	CO2	
3.H	Urea Application	CO2	
3.I.	Other carbon-containing fertlizers	CO2	
3.J.	Other	CO2	
3.J.	Other	CH4	
3.J.	Other	N2O	
4.A.2	Agriculture (indirect CO2 emissions)	CO2	
4.B.2	Land Converted to Forest Land	CO2	
4.C.1	Land Converted to Cropland	CO2	
4.C.2	Grassland Remaining Grassland	CO2	
4.D.1.1	Peat Extraction Remaining Peat Extraction	CO2	
4.D.1.2	Flooded Land Remaining Flooded Land	CO2	
4.D.1.3	Other Wetlands Remaining Other Wetlands	CO2	
4.D.2	Land Converted to Wetlands	CO2	
4.E.1	Settlements Remaining Settlements	CO2	
4.E.2	Land Converted to Settlements	CO2	
4.F.1	Other Land Remaining Other Land	CO2	

IPCC Category code	IPCC source categories	GHG	Level Assessment
4.F.2	Land Converted to Other Land	CO2	
4.G	Harvested Wood Products	CO2	
4(I).	Direct and indirect N2O emissions from N inputs to managed soils	N2O	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH4	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	N2O	
4(III).Direct	and indirect N2O emissions from N mineralization/immobilization	N2O	
4(IV)	Biomass Burning	CO2	
4(V)	Biomass Burning	N2O	
4(V)	Other	CO2	
4(V)	Other	CH4	
4.H	Other	N2O	
4.H	LULUCF (indirect CO2 emissions)	CO2	
4.H	Biological Treatment of Solid Waste	CH4	
5.A	Biological Treatment of Solid Waste	N2O	
5.B	Incineration and Open Burning of Waste	CO2	
5.B	Incineration and Open Burning of Waste	CH4	
5.C	Incineration and Open Burning of Waste	N2O	
5.C	Wastewater Treatment and Discharge	N2O	
5.C	Other	CO2	
5.D	Other	CH4	
5.E	Other	N2O	
5.E	Waste (indirect CO2 emissions)	CO2	
5.E	Other	CO2	
6.	Other	CH4	
6.	Other	N2O	
6.	Other	Aggregate F-gases	
6.	Other (indirect CO2 emissions)	CO2	

Table I.4 Key categories analysis without LULUCF – Level assessment for 1990

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	X
1.A.3.b	Road Transportation	CO2	X
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Liquid Fuels	CO2	X
1.B.1	Fugitive emissions from Solid Fuels	CH4	X
2.A.1	Cement Production	CO2	X
2.B.1	Ammonia Production	CO2	X
2.B.2	Nitric Acid Production	N2O	X
2.B.9	Fluorochemical Production	Aggregate F-gases	X
2.C.2	Ferroalloys Production	CO2	X
3.A	Enteric Fermentation	CH4	X
3.B	Manure Management	CH4	X
3.D.1	Direct N2O Emissions From Managed Soils	N2O	X
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	X
5.A	Solid Waste Disposal	CH4	X
5.D	Wastewater Treatment and Discharge	CH4	X
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CO2	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Peat	CO2	
1.A.1	Fuel combustion - Energy Industries - Peat	CH4	
1.A.1	Fuel combustion - Energy Industries - Peat	N2O	
1.A.1	Fuel combustion - Energy Industries - Biomass	CH4	
1.A.1	Fuel combustion - Energy Industries - Biomass	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other	CH4	

IPCC Category code	IPCC source categories	GHG	Level Assessment
	Fossil Fuels		
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	N2O	
1.A.3.a	Domestic Aviation	CO2	
1.A.3.a	Domestic Aviation	CH4	
1.A.3.a	Domestic Aviation	N2O	
1.A.3.b	Road Transportation	CH4	
1.A.3.b	Road Transportation	N2O	
1.A.3.c	Railways	CO2	
1.A.3.c	Railways	CH4	
1.A.3.c	Railways	N2O	
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CO2	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CH4	
1.A.3.d	Domestic Navigation - Gaseous Fuels	N2O	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CO2	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CH4	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	N2O	
1.A.3.d	Domestic Navigation - Biomass Fuels	CH4	
1.A.3.d	Domestic Navigation - Biomass Fuels	N2O	
1.A.3.e	Other Transportation	CO2	
1.A.3.e	Other Transportation	CH4	
1.A.3.e	Other Transportation	N2O	
1.A.4	Other Sectors - Liquid Fuels	CH4	
1.A.4	Other Sectors - Liquid Fuels	N2O	
1.A.4	Other Sectors - Solid Fuels	CO2	
1.A.4	Other Sectors - Solid Fuels	CH4	
1.A.4	Other Sectors - Solid Fuels	N2O	
1.A.4	Other Sectors - Gaseous Fuels	CO2	
1.A.4	Other Sectors - Gaseous Fuels	CH4	
1.A.4	Other Sectors - Gaseous Fuels	N2O	
1.A.4	Other Sectors - Other Fossil Fuels	CO2	
1.A.4	Other Sectors - Other Fossil Fuels	CH4	
1.A.4	Other Sectors - Other Fossil Fuels	N2O	
1.A.4	Other Sectors - Peat	CO2	
1.A.4	Other Sectors - Peat	CH4	
1.A.4	Other Sectors - Peat	N2O	
1.A.4	Other Sectors - Biomass	CH4	
1.A.4	Other Sectors - Biomass	N2O	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CO2	

IPCC Category code	IPCC source categories	GHG	Level Assessment
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Peat	CO2	
1.A.5	Other (Not specified elsewhere) - Peat	CH4	
1.A.5	Other (Not specified elsewhere) - Peat	N2O	
1.A.5	Other (Not specified elsewhere) - Biomass	CH4	
1.A.5	Other (Not specified elsewhere) - Biomass	N2O	
1.B.1	Fugitive emissions from Solid Fuels	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH4	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO2	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CO2	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	N2O	
1.B.2.d	Fugitive Emissions from Fuels - Other	CO2	
1.B.2.d	Fugitive Emissions from Fuels - Other	CH4	
1.B.2.d	Fugitive Emissions from Fuels - Other	N2O	
1.C	CO2 Transport and Storage	CO2	
2.A.2	Lime Production	CO2	
2.A.3	Glass Production	CO2	
2.A.4	Other Process Uses of Carbonates	CO2	
2.B.1	Ammonia Production	CH4	
2.B.1	Ammonia Production	N2O	
2.B.3	Adipic Acid Production	CO2	
2.B.3	Adipic Acid Production	N2O	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	CO2	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	
2.B.5	Carbide Production	CO2	
2.B.5	Carbide Production	CH4	
2.B.6	Titanium Dioxide Production	CO2	
2.B.7	Soda Ash Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CH4	
2.B.10	Other	CO2	
2.B.10	Other	CH4	
2.B.10	Other	N2O	
2.B.10	Other	Aggregate F-gases	
2.C.1	Iron and Steel Production	CO2	
2.C.1	Iron and Steel Production	CH4	
2.C.2	Ferroalloys Production	CH4	
2.C.3	Aluminium Production	CO2	
2.C.3	Aluminium Production	PFCs	
2.C.3	Aluminium Production	SF6	
2.C.4	Magnesium Production	CO2	
2.C.4	Magnesium Production	HFCs	
2.C.4	Magnesium Production	PFCs	
2.C.4	Magnesium Production	SF6	
2.C.4	Magnesium Production	Unspecified mix of HFCs and PFCs	
2.C.5	Lead Production	CO2	
2.C.6	Zinc Production	CO2	
2.C.7	Other	CO2	

IPCC Category code	IPCC source categories	GHG	Level Assessment
2.C.7	Other	CH4	
2.C.7	Other	N2O	
2.C.7	Other	Aggregate F-gases	
2.D	Non-energy Products from Fuels and Solvent Use	CO2	
2.D	Non-energy Products from Fuels and Solvent Use	CH4	
2.D	Non-energy Products from Fuels and Solvent Use	N2O	
2.E	Electronics Industry	Aggregate F-gases	
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	
2.F.2	Foam Blowing Agents	Aggregate F-gases	
2.F.3	Fire Protection	Aggregate F-gases	
2.F.4	Aerosols	Aggregate F-gases	
2.F.5	Solvents	Aggregate F-gases	
2.F.6	Other Applications	Aggregate F-gases	
2.G	Other Product Manufacture and Use	CO2	
2.G	Other Product Manufacture and Use	CH4	
2.G	Other Product Manufacture and Use	N2O	
2.G	Other Product Manufacture and Use	Aggregate F-gases	
2.H	Other	CO2	
2.H	Other	CH4	
2.H	Other	N2O	
2.H	Other	Aggregate F-gases	
3.B	Manure Management	N2O	
3.C	Rice Cultivation	CH4	
3.D	Agricultural Soils	CH4	
3.E	Prescribed burning of savannas	CH4	
3.E	Prescribed burning of savannas	N2O	
3.F	Field burning of agricultural residues	CH4	
3.F	Field burning of agricultural residues	N2O	
3.G	Liming	CO2	
3.H	Urea Application	CO2	
3.I.	Other carbon-containing fertlizers	CO2	
3.J.	Other	CO2	
3.J.	Other	CH4	
3.J.	Other	N2O	
5.A	Solid Waste Disposal	CO2	
5.B	Biological Treatment of Solid Waste	CH4	
5.B	Biological Treatment of Solid Waste	N2O	
5.C	Incineration and Open Burning of Waste	CO2	
5.C	Incineration and Open Burning of Waste	CH4	
5.C	Incineration and Open Burning of Waste	N2O	
5.D	Wastewater Treatment and Discharge	N2O	
5.E	Other	CO2	
5.E	Other	CH4	
5.E	Other	N2O	
6.	Other	CO2	
6.	Other	CH4	
6.	Other	N2O	

IPCC Category code	IPCC source categories	GHG	Level Assessment
6.	Other	Aggregate F-gases	
6.	Other (indirect CO2 emissions)	CO2	

Table I.5 Key categories analysis with LULUCF – Trend assessment for 2023

IPCC Category code	IPCC source categories	GHG	Trend Assessment
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	X
1.A.3.b	Road Transportation	CO2	X
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Gaseous Fuels	CO2	X
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO2	X
2.A.1	Cement Production	CO2	X
2.B.10	Other	CO2	X
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	X
3.A	Enteric Fermentation	CH4	X
3.D.1	Direct N2O Emissions From Managed Soils	N2O	X
5.A	Solid Waste Disposal	CH4	X
5.D	Wastewater Treatment and Discharge	CH4	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	X
1.B.1	Fugitive emissions from Solid Fuels	CH4	X
2.B.1	Ammonia Production	CO2	X
2.B.2	Nitric Acid Production	N2O	X
4.C.2	Land Converted to Grassland	CO2	X
4(IV)	Biomass Burning	CH4	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2	X
4.G	Harvested Wood Products	CO2	X
1.A.3.a	Domestic Aviation	CO2	
2.C.3	Aluminium Production	CO2	
3.B	Manure Management	CH4	
3.B	Manure Management	N2O	
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	
4.A.1	Forest Land Remaining Forest Land	CO2	
4.B.1	Cropland Remaining Cropland	CO2	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CO2	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Peat	CO2	
1.A.1	Fuel combustion - Energy Industries - Peat	CH4	
1.A.1	Fuel combustion - Energy Industries - Peat	N2O	
1.A.1	Fuel combustion - Energy Industries - Biomass	CH4	
1.A.1	Fuel combustion - Energy Industries - Biomass	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid	CH4	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
	Fuels		
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	N2O	
1.A.3.a	Domestic Aviation	CH4	
1.A.3.a	Domestic Aviation	N2O	
1.A.3.b	Road Transportation	CH4	
1.A.3.b	Road Transportation	N2O	
1.A.3.c	Railways	CO2	
1.A.3.c	Railways	CH4	
1.A.3.c	Railways	N2O	
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CO2	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CH4	
1.A.3.d	Domestic Navigation - Gaseous Fuels	N2O	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CO2	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CH4	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	N2O	
1.A.3.d	Domestic Navigation - Biomass Fuels	CH4	
1.A.3.d	Domestic Navigation - Biomass Fuels	N2O	
1.A.3.e	Other Transportation	CO2	
1.A.3.e	Other Transportation	CH4	
1.A.3.e	Other Transportation	N2O	
1.A.4	Other Sectors - Liquid Fuels	CH4	
1.A.4	Other Sectors - Liquid Fuels	N2O	
1.A.4	Other Sectors - Solid Fuels	CO2	
1.A.4	Other Sectors - Solid Fuels	CH4	
1.A.4	Other Sectors - Solid Fuels	N2O	
1.A.4	Other Sectors - Gaseous Fuels	CH4	
1.A.4	Other Sectors - Gaseous Fuels	N2O	
1.A.4	Other Sectors - Other Fossil Fuels	CO2	
1.A.4	Other Sectors - Other Fossil Fuels	CH4	
1.A.4	Other Sectors - Other Fossil Fuels	N2O	
1.A.4	Other Sectors - Peat	CO2	
1.A.4	Other Sectors - Peat	CH4	
1.A.4	Other Sectors - Peat	N2O	
1.A.4	Other Sectors - Biomass	CH4	
1.A.4	Other Sectors - Biomass	N2O	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Peat	CO2	
1.A.5	Other (Not specified elsewhere) - Peat	CH4	
1.A.5	Other (Not specified elsewhere) - Peat	N2O	
1.A.5	Other (Not specified elsewhere) - Biomass	CH4	
1.A.5	Other (Not specified elsewhere) - Biomass	N2O	
1.B.1	Fugitive emissions from Solid Fuels	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH4	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO2	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CO2	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	N2O	
1.B.2.d	Fugitive Emissions from Fuels - Other	CO2	
1.B.2.d	Fugitive Emissions from Fuels - Other	CH4	
1.B.2.d	Fugitive Emissions from Fuels - Other	N2O	
1.C	CO2 Transport and Storage	CO2	
1.	Energy (indirect CO2 emissions)	CO2	
2.A.2	Lime Production	CO2	
2.A.3	Glass Production	CO2	
2.A.4	Other Process Uses of Carbonates	CO2	
2.B.1	Ammonia Production	CH4	
2.B.1	Ammonia Production	N2O	
2.B.3	Adipic Acid Production	CO2	
2.B.3	Adipic Acid Production	N2O	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	CO2	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	
2.B.5	Carbide Production	CO2	
2.B.5	Carbide Production	CH4	
2.B.6	Titanium Dioxide Production	CO2	
2.B.7	Soda Ash Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CH4	
2.B.9	Fluorochemical Production	Aggregate F-gases	
2.B.10	Other	CH4	
2.B.10	Other	N2O	
2.B.10	Other	Aggregate F-gases	
2.C.1	Iron and Steel Production	CO2	
2.C.1	Iron and Steel Production	CH4	
2.C.2	Ferroalloys Production	CO2	
2.C.2	Ferroalloys Production	CH4	
2.C.3	Aluminium Production	PFCs	
2.C.3	Aluminium Production	SF6	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
2.C.4	Magnesium Production	CO2	
2.C.4	Magnesium Production	HFCs	
2.C.4	Magnesium Production	PFCs	
2.C.4	Magnesium Production	SF6	
2.C.4	Magnesium Production	Unspecified mix of HFCs and PFCs	
2.C.5	Lead Production	CO2	
2.C.6	Zinc Production	CO2	
2.C.7	Other	CO2	
2.C.7	Other	CH4	
2.C.7	Other	N2O	
2.C.7	Other	Aggregate F-gases	
2.D	Non-energy Products from Fuels and Solvent Use	CO2	
2.D	Non-energy Products from Fuels and Solvent Use	CH4	
2.D	Non-energy Products from Fuels and Solvent Use	N2O	
2.E	Electronics Industry	N2O	
2.E	Electronics Industry	Aggregate F-gases	
2.F.2	Foam Blowing Agents	Aggregate F-gases	
2.F.3	Fire Protection	Aggregate F-gases	
2.F.4	Aerosols	Aggregate F-gases	
2.F.5	Solvents	Aggregate F-gases	
2.F.6	Other Applications	Aggregate F-gases	
2.G	Other Product Manufacture and Use	CO2	
2.G	Other Product Manufacture and Use	CH4	
2.G	Other Product Manufacture and Use	N2O	
2.G	Other Product Manufacture and Use	Aggregate F-gases	
2.H	Other	CO2	
2.H	Other	CH4	
2.H	Other	N2O	
2.H	Other	Aggregate F-gases	
2.	Industrial Proccesses and Produc Use (indirect CO2 emissions)	CO2	
3.C	Rice Cultivation	CH4	
3.D	Agricultural Soils	CH4	
3.E	Prescribed burning of savannas	CH4	
3.E	Prescribed burning of savannas	N2O	
3.F	Field burning of agricultural residues	CH4	
3.F	Field burning of agricultural residues	N2O	
3.G	Liming	CO2	
3.H	Urea Application	CO2	
3.I.	Other carbon-containing fertlizers	CO2	
3.J.	Other	CO2	
3.J.	Other	CH4	
3.J.	Other	N2O	
3.	Agriculture (indirect CO2 emissions)	CO2	
4.A.2	Land Converted to Forest Land	CO2	
4.B.2	Land Converted to Cropland	CO2	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
4.C.1	Grassland Remaining Grassland	CO2	
4.D.1.1	Peat Extraction Remaining Peat Extraction	CO2	
4.D.1.2	Flooded Land Remaining Flooded Land	CO2	
4.D.1.3	Other Wetlands Remaining Other Wetlands	CO2	
4.D.2	Land Converted to Wetlands	CO2	
4.E.1	Settlements Remaining Settlements	CO2	
4.E.2	Land Converted to Settlements	CO2	
4.F.1	Other Land Remaining Other Land	CO2	
4.F.2	Land Converted to Other Land	CO2	
4(I).	Direct and indirect N2O emissions from N inputs to managed soils	N2O	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH4	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	N2O	
4(III).Direct	and indirect N2O emissions from N mineralization/immobilization	N2O	
4(IV)	Biomass Burning	CO2	
4(IV)	Biomass Burning	N2O	
4.H	Other	CO2	
4.H	Other	CH4	
4.H	Other	N2O	
4.	LULUCF (indirect CO2 emissions)	CO2	
5.B	Biological Treatment of Solid Waste	CH4	
5.B	Biological Treatment of Solid Waste	N2O	
5.C	Incineration and Open Burning of Waste	CO2	
5.C	Incineration and Open Burning of Waste	CH4	
5.C	Incineration and Open Burning of Waste	N2O	
5.D	Wastewater Treatment and Discharge	N2O	
5.E	Other	CO2	
5.E	Other	CH4	
5.E	Other	N2O	
5.	Waste (indirect CO2 emissions)	CO2	
6.	Other	CO2	
6.	Other	CH4	
6.	Other	N2O	
6.	Other	Aggregate F-gases	
6.	Other (indirect CO2 emissions)	CO2	

Table I.6 Key categories analysis without LULUCF – Trend assessment for 2023

IPCC Category code	IPCC source categories	GHG	Trend Assessment
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CO2	X
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	X
1.A.3.b	Road Transportation	CO2	X
1.A.3.d	Domestic Navigation - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Liquid Fuels	CO2	X
1.A.4	Other Sectors - Gaseous Fuels	CO2	X
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CO2	X
2.A.1	Cement Production	CO2	X
2.B.10	Other	CO2	X
2.F.1	Refrigeration and Air conditioning	Aggregate F-gases	X
3.A	Enteric Fermentation	CH4	X
3.D.1	Direct N2O Emissions From Managed Soils	N2O	X
5.A	Solid Waste Disposal	CH4	X
5.D	Wastewater Treatment and Discharge	CH4	X
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2	X
1.B.1	Fugitive emissions from Solid Fuels	CH4	X
2.B.1	Ammonia Production	CO2	X
2.B.2	Nitric Acid Production	N2O	X
1.A.3.a	Domestic Aviation	CO2	
2.C.3	Aluminium Production	CO2	
3.B	Manure Management	CH4	
3.B	Manure Management	N2O	
3.D.2	Indirect N2O Emissions From Managed Soils	N2O	
4.C.2	Land Converted to Grassland	CO2	
4(IV)	Biomass Burning	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2	
4.G	Harvested Wood Products	CO2	
4.A.1	Forest Land Remaining Forest Land	CO2	
4.B.1	Cropland Remaining Cropland	CO2	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Liquid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Solid Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Gaseous Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CO2	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	CH4	
1.A.1	Fuel combustion - Energy Industries - Other Fossil Fuels	N2O	
1.A.1	Fuel combustion - Energy Industries - Peat	CO2	
1.A.1	Fuel combustion - Energy Industries - Peat	CH4	
1.A.1	Fuel combustion - Energy Industries - Peat	N2O	
1.A.1	Fuel combustion - Energy Industries - Biomass	CH4	
1.A.1	Fuel combustion - Energy Industries - Biomass	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid	CH4	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
	Fuels		
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CO2	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Peat	N2O	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	CH4	
1.A.2	Fuel combustion - Manufacturing Industries and Construction - Biomass	N2O	
1.A.3.a	Domestic Aviation	CH4	
1.A.3.a	Domestic Aviation	N2O	
1.A.3.b	Road Transportation	CH4	
1.A.3.b	Road Transportation	N2O	
1.A.3.c	Railways	CO2	
1.A.3.c	Railways	CH4	
1.A.3.c	Railways	N2O	
1.A.3.d	Domestic Navigation - Liquid Fuels	CH4	
1.A.3.d	Domestic Navigation - Liquid Fuels	N2O	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CO2	
1.A.3.d	Domestic Navigation - Gaseous Fuels	CH4	
1.A.3.d	Domestic Navigation - Gaseous Fuels	N2O	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CO2	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	CH4	
1.A.3.d	Domestic Navigation - Other Fossil Fuels	N2O	
1.A.3.d	Domestic Navigation - Biomass Fuels	CH4	
1.A.3.d	Domestic Navigation - Biomass Fuels	N2O	
1.A.3.e	Other Transportation	CO2	
1.A.3.e	Other Transportation	CH4	
1.A.3.e	Other Transportation	N2O	
1.A.4	Other Sectors - Liquid Fuels	CH4	
1.A.4	Other Sectors - Liquid Fuels	N2O	
1.A.4	Other Sectors - Solid Fuels	CO2	
1.A.4	Other Sectors - Solid Fuels	CH4	
1.A.4	Other Sectors - Solid Fuels	N2O	
1.A.4	Other Sectors - Gaseous Fuels	CH4	
1.A.4	Other Sectors - Gaseous Fuels	N2O	
1.A.4	Other Sectors - Other Fossil Fuels	CO2	
1.A.4	Other Sectors - Other Fossil Fuels	CH4	
1.A.4	Other Sectors - Other Fossil Fuels	N2O	
1.A.4	Other Sectors - Peat	CO2	
1.A.4	Other Sectors - Peat	CH4	
1.A.4	Other Sectors - Peat	N2O	
1.A.4	Other Sectors - Biomass	CH4	
1.A.4	Other Sectors - Biomass	N2O	
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	CH4	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
1.A.5	Other (Not specified elsewhere) - Liquid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Solid Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Gaseous Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CO2	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	CH4	
1.A.5	Other (Not specified elsewhere) - Other Fossil Fuels	N2O	
1.A.5	Other (Not specified elsewhere) - Peat	CO2	
1.A.5	Other (Not specified elsewhere) - Peat	CH4	
1.A.5	Other (Not specified elsewhere) - Peat	N2O	
1.A.5	Other (Not specified elsewhere) - Biomass	CH4	
1.A.5	Other (Not specified elsewhere) - Biomass	N2O	
1.B.1	Fugitive emissions from Solid Fuels	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CO2	
1.B.2.a	Fugitive Emissions from Fuels - Oil and Natural Gas - Oil	CH4	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CO2	
1.B.2.b	Fugitive Emissions from Fuels - Oil and Natural Gas - Natural Gas	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CO2	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	CH4	
1.B.2.c	Fugitive Emissions from Fuels - Venting and flaring	N2O	
1.B.2.d	Fugitive Emissions from Fuels - Other	CO2	
1.B.2.d	Fugitive Emissions from Fuels - Other	CH4	
1.B.2.d	Fugitive Emissions from Fuels - Other	N2O	
1.C	CO2 Transport and Storage	CO2	
1.	Energy (indirect CO2 emissions)	CO2	
2.A.2	Lime Production	CO2	
2.A.3	Glass Production	CO2	
2.A.4	Other Process Uses of Carbonates	CO2	
2.B.1	Ammonia Production	CH4	
2.B.1	Ammonia Production	N2O	
2.B.3	Adipic Acid Production	CO2	
2.B.3	Adipic Acid Production	N2O	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	CO2	
2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	
2.B.5	Carbide Production	CO2	
2.B.5	Carbide Production	CH4	
2.B.6	Titanium Dioxide Production	CO2	
2.B.7	Soda Ash Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CO2	
2.B.8	Petrochemical and Carbon Black Production	CH4	
2.B.9	Fluorochemical Production	Aggregate F-gases	
2.B.10	Other	CH4	
2.B.10	Other	N2O	
2.B.10	Other	Aggregate F-gases	
2.C.1	Iron and Steel Production	CO2	
2.C.1	Iron and Steel Production	CH4	
2.C.2	Ferroalloys Production	CO2	
2.C.2	Ferroalloys Production	CH4	
2.C.3	Aluminium Production	PFCs	
2.C.3	Aluminium Production	SF6	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
2.C.4	Magnesium Production	CO2	
2.C.4	Magnesium Production	HFCs	
2.C.4	Magnesium Production	PFCs	
2.C.4	Magnesium Production	SF6	
2.C.4	Magnesium Production	Unspecified mix of HFCs and PFCs	
2.C.5	Lead Production	CO2	
2.C.6	Zinc Production	CO2	
2.C.7	Other	CO2	
2.C.7	Other	CH4	
2.C.7	Other	N2O	
2.C.7	Other	Aggregate F-gases	
2.D	Non-energy Products from Fuels and Solvent Use	CO2	
2.D	Non-energy Products from Fuels and Solvent Use	CH4	
2.D	Non-energy Products from Fuels and Solvent Use	N2O	
2.E	Electronics Industry	N2O	
2.E	Electronics Industry	Aggregate F-gases	
2.F.2	Foam Blowing Agents	Aggregate F-gases	
2.F.3	Fire Protection	Aggregate F-gases	
2.F.4	Aerosols	Aggregate F-gases	
2.F.5	Solvents	Aggregate F-gases	
2.F.6	Other Applications	Aggregate F-gases	
2.G	Other Product Manufacture and Use	CO2	
2.G	Other Product Manufacture and Use	CH4	
2.G	Other Product Manufacture and Use	N2O	
2.G	Other Product Manufacture and Use	Aggregate F-gases	
2.H	Other	CO2	
2.H	Other	CH4	
2.H	Other	N2O	
2.H	Other	Aggregate F-gases	
2.	Industrial Proccesses and Produc Use (indirect CO2 emissions)	CO2	
3.C	Rice Cultivation	CH4	
3.D	Agricultural Soils	CH4	
3.E	Prescribed burning of savannas	CH4	
3.E	Prescribed burning of savannas	N2O	
3.F	Field burning of agricultural residues	CH4	
3.F	Field burning of agricultural residues	N2O	
3.G	Liming	CO2	
3.H	Urea Application	CO2	
3.I.	Other carbon-containing fertlizers	CO2	
3.J.	Other	CO2	
3.J.	Other	CH4	
3.J.	Other	N2O	
3.	Agriculture (indirect CO2 emissions)	CO2	
4.A.2	Land Converted to Forest Land	CO2	
4.B.2	Land Converted to Cropland	CO2	

IPCC Category code	IPCC source categories	GHG	Trend Assessment
4.C.1	Grassland Remaining Grassland	CO2	
4.D.1.1	Peat Extraction Remaining Peat Extraction	CO2	
4.D.1.2	Flooded Land Remaining Flooded Land	CO2	
4.D.1.3	Other Wetlands Remaining Other Wetlands	CO2	
4.D.2	Land Converted to Wetlands	CO2	
4.E.1	Settlements Remaining Settlements	CO2	
4.E.2	Land Converted to Settlements	CO2	
4.F.1	Other Land Remaining Other Land	CO2	
4.F.2	Land Converted to Other Land	CO2	
4(I).	Direct and indirect N2O emissions from N inputs to managed soils	N2O	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CO2	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	CH4	
4(II).	Emissions and removals from drainage and rewetting and other management of organic and mineral soils	N2O	
4(III).Direct	and indirect N2O emissions from N mineralization/immobilization	N2O	
4(IV)	Biomass Burning	CO2	
4(IV)	Biomass Burning	N2O	
4.H	Other	CO2	
4.H	Other	CH4	
4.H	Other	N2O	
4.	LULUCF (indirect CO2 emissions)	CO2	
5.B	Biological Treatment of Solid Waste	CH4	
5.B	Biological Treatment of Solid Waste	N2O	
5.C	Incineration and Open Burning of Waste	CO2	
5.C	Incineration and Open Burning of Waste	CH4	
5.C	Incineration and Open Burning of Waste	N2O	
5.D	Wastewater Treatment and Discharge	N2O	
5.E	Other	CO2	
5.E	Other	CH4	
5.E	Other	N2O	
5.	Waste (indirect CO2 emissions)	CO2	
6.	Other	CO2	
6.	Other	CH4	
6.	Other	N2O	
6.	Other	Aggregate F-gases	
6.	Other (indirect CO2 emissions)	CO2	

The results of the key categories analysis for the year 2023 are summed up in ***Table I.7***.

Table I.7 Source Category Analysis Summary for 2023

Quantitative method used	Tier 1				
IPCC source categories	GHG	Criteria for identification		Key category excluding LULUCF	Key category including LULUCF
		Level	Trend		
ENERGY SECTOR					
Fuel combustion - Energy Industries - Liquid Fuels	CO2	X	X	X	X
Fuel combustion - Energy Industries - Solid Fuels	CO2	X	X	X	X
Fuel combustion - Energy Industries - Gaseous Fuels	CO2	X	X	X	X
Fuel combustion - Manufacturing Industries and Construction - Liquid Fuels	CO2	X	X	X	X
Fuel combustion - Manufacturing Industries and Construction - Gaseous Fuels	CO2	X	X	X	X
Fuel combustion - Manufacturing Industries and Construction - Solid Fuels	CO2		X	X	X
Fuel combustion - Manufacturing Industries and Construction - Other Fossil Fuels	CO2		X		X
Domestic Aviation	CO2	X		X	X
Road Transportation	CO2	X	X	X	X
Domestic Navigation - Liquid Fuels	CO2	X	X	X	X
Other Sectors - Liquid Fuels	CO2	X	X	X	X
Other Sectors - Gaseous Fuels	CO2	X	X	X	X
Other (Not specified elsewhere) - Liquid Fuels	CO2	X	X	X	X
Fugitive emissions from Solid Fuels	CH4		X	X	X
INDUSTRIAL PROCESSES SECTOR					
Cement Production	CO2	X	X	X	X
Ammonia Production	CO2		X	X	X
Other	CO2	X	X	X	X
Nitric Acid Production	N2O		X	X	X
Aluminium Production	CO2	X		X	X
Refrigeration and Air conditioning	Aggregate F-gases	X	X	X	X
AGRICULTURE					
Enteric Fermentation	CH4	X	X	X	X
Manure Management	CH4	X		X	X
Manure Management	N2O	X		X	X
Direct N2O Emissions From Managed Soils	N2O	X	X	X	X
Indirect N2O Emissions From Managed Soils	N2O	X		X	X
WASTE					
Solid Waste Disposal	CH4	X	X	X	X
Wastewater Treatment and Discharge	CH4	X	X	X	X
LULUCF					
Biomass Burning	CH4	X	X		X
Forest Land Remaining Forest Land	CO2	X			X
Cropland Remaining Cropland	CO2	X			X
Land Converted to Grassland	CO2	X	X		X
Harvested Wood Products	CO2		X		X

Annex II: Detailed discussion of methodology and data for estimating CO_2 and other GHG emissions from fossil fuel combustion

General discussion

The calculation of CO2 emissions from the energy sector is mainly performed by the application of a Tier 2 methodology based on 2006 IPCC guidelines. Emissions are estimated multiplying the consumption per fuel with the relative emission factor.

- The national energy balance is the main source of information regarding fuel consumption per fuel and sub-sector. Further analysis of fuel consumption by technology within each sub-sector is made on the basis of the assumptions presented in Chapter 3.
- Verified reports from installations under the EU ETS is a source of plant specific activity data and in order to calculate plant specific CO_2 emission factors per sector (IPCC source category) and fuel.
- Emission factors of carbon dioxide by fuel depend exclusively on fuel characteristics (see Table 3.13 which presents emission factors of carbon dioxide by fuel).

The national energy balance could be found in the following links:

https://ec.europa.eu/eurostat/cache/visualisations/energy-balances/enbal.html

Use of data from EU-ETS verified reports in Energy sector

In 2004 the first guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to the EU Emission Trading Scheme (ETS) Directive (2003/87/EC) were implemented.

These were updated in 2007 and are available from the EU Commission website. The Greek emission inventory only includes data from plants using higher tier methods as defined in the EU decision establishing guidelines for monitoring and reporting. In the Guidelines the specific methods for determining carbon contents, oxidation factor and calorific value are specified. In the Greek inventory plant based CO2 emission factors have been derived for power plants combusting lignite, oil and natural gas, refineries combusting LPG, refinery gas, petcoke, naptha, HFO and natural gas, manufacturing industries (cement, lime ceramics etc) combusting coal, petcoke, HFO and alternative fuels (e.g. scrap tyres). For all these sources the EU ETS reports use only high tier methods. The EU ETS data have been applied for the years 2005 - 2020. The EU ETS reporting guidelines emphasizes the need for a high quality reporting through ensuring completeness, consistency, accuracy, transparency and faithfulness. The quality criteria as defined under the EU ETS reporting guidelines are in complete agreement with the principles in the IPCC good practice guidance.

The determination of the variables needed for the emission calculation has to be done in accordance with international standards. It is not possible to list all the relevant standards here, but an overview is available in annex 1, chapter 13 of the EU ETS guidelines. There are also demands concerning sampling methods and frequency of analysis. As an example the tier 3 regarding fuel flow for fuel combustion, corresponds

to a determination of the fuel consumption with an maximum uncertainty of 2.5 % taking into account possible effects of stock change. Tier 4 is a maximum uncertainty of 1.5 %. These uncertainties are very low and are in line with what could be expected from a well-functioning energy statistics system. The operators shall establish, document, implement and maintain effective data acquisition and handling activities. This means assigning responsibilities for the quality process, as well as quality assurance, reviews and validation of data. Furthermore, an independent verification ensuring that emissions have been monitored in accordance with the EU ETS guidelines and that reliable and correct emission data are reported. The demands for the QA/QC system in the EU ETS guidelines are fully comparable to the requirements in the IPCC good practice guidance.

The EU-ETS reporting is also a source of plant specific activity data. The procedure followed for reconciling the use of bottom up data with the energy balance (in order to ensure no double counting/omissions) is the following: A cross-checking between energy consumption data derived from national energy balance and plant specific energy consumption data of major industrial plants derived from verified ETS reports is performed. In order to avoid any double counting/omissions of fuel used, the findings of the above quality check are communicated to the competent department of MEEN that is the compiler of national energy balance. Then, jointly it is decided, which fuel quantities will be used as activity data for emission calculations. By this annual quality check both the national energy balance and the energy consumption used in emission calculations is verified and get improved

Other information

The alternative fuels (scrap tires, cable coating etc) that are used in greek cement plants are reported under source category 1A2f – other fuels. The variation of CO2 IEF of alternative fuels along the time series is due to the following reasons:

- The amount of each type of alternative fuel consumed per year may vary due to operational conditions / limitations of the cement plants.
- The properties, as NCV and carbon content, of each alternative fuel type present significant fluctuations, depending their previous use, origin etc.

Table II.1 Carbon intensity of total power generation

Year	CO2 emissions from classical power production, kt*	All products output by public and autoproducer power stations, PJ**	EF, tCO2/TJ	EF, kgCO2/Mwh
1990	40,846	126.01	324.15	1,166.94
1991	39,681	128.93	307.76	1,107.95
1992	42,057	134.68	312.28	1,124.20
1993	41,953	138.23	303.51	1,092.64
1994	43,706	146.25	298.85	1,075.87
1995	42,427	149.59	283.63	1,021.07
1996	41,345	153.24	269.80	971.29
1997	44,767	157.65	283.96	1,022.26
1998	47,237	167.83	281.45	1,013.22
1999	47,874	179.78	266.30	958.67
2000	51,693	195.01	265.08	954.29
2001	52,193	194.51	268.33	965.98
2002	51,521	197.74	260.55	937.97
2003	52,952	212.43	249.28	897.39
2004	54,084	215.46	251.01	903.65
2005	54,507	218.12	249.89	899.62
2006	51,636	221.19	233.45	840.41
2007	54,995	230.32	238.77	859.58
2008	54,390	231.33	235.12	846.42
2009	51,185	222.96	229.56	826.43
2010	48,835	208.55	234.16	842.98
2011	50,971	216.23	235.73	848.62
2012	51,491	221.34	232.63	837.47
2013	44,608	207.49	214.99	773.98
2014	41,078	183.78	223.52	804.66
2015	41,078	188.84	217.53	783.10
2016	31,778	198.11	160.41	577.46
2017	35,242	201.10	175.25	630.90
2018	33,543	193.91	172.98	622.73
2019	27,778	177.26	156.71	564.16
2020	20,523	175.91	116.67	420.02
2021	20,540	198.95	103.24	371.68
2022	19,376	191.16	101.357	364.884
2023	15,954	181.09	88.099	317.158

*CO2 emissions from all fossil fuel combustion for gross electricity and heat production by public thermal power and combined heat and power plants and by autoproducer thermal power and combined heat and power plants. Emissions from heat only plants are not included.

**Gross electricity produced and any heat sold to third parties (combined heat and power - CHP) by public and autoproducer power and combined heat and power plants. Includes electricity production from renewable sources and nuclear power. (source: energy balance)

Annex III: CO_2 reference approach and comparison with sectoral approach, and relevant information on the national energy balance

The Reference Approach requires statistics for production of fuels and their external trade as well as changes in their stocks. It also needs a limited number of figures for the consumption of fuels used for non-energy purposes where carbon may be stored. It uses a simple assumption: once carbon is brought into a national economy in fuel, it is either saved in some way (e.g., in increases of fuel stocks, stored in products, left unoxidised in ash) or it must be released to the atmosphere.

The estimation process is divided in six steps that are described below.

Step 1: Estimation of apparent consumption.

This step concerns the estimation of apparent consumption in natural units or in the units commonly used for the recording of the relative fuel amounts. For secondary fuels production data are not included in the apparent consumption calculation, since they are already accounted for in the primary fuel consumption, from which they derive. Therefore, the apparent consumption of primary fuels is estimated by the following equation:

Apparent consumption = Primary production + Imports - Exports – International bunkers + Stock change

The apparent consumption of secondary fuels is estimated by the following equation:

Apparent consumption = Imports - Exports - International bunkers + Stock change

Step 2: Conversion of fuel data to a common energy unit.

This step concerns the conversion of apparent consumption, which was estimated in the first step in natural units, in a common energy unit (e.g. TJ). This conversion is based on net calorific value of fuels (see ***Tables III.1***).

Step 3: Estimation of carbon content.

Total carbon included in each fuel is calculated by multiplying energy consumption by an emission factor (see ***Table III.1***) that reflects the amount of carbon per energy unit for each fuel. The result gives the maximum amount of carbon that could be potentially released if all carbon in the fuels were converted to CO_2.

Step 4: Estimation of carbon stored in products.

Depending on the end use, non-energy uses of fuels can result in the storage of some or all of the carbon contained in the fuel to the non-energy product. The non-energy consumption of fuels is

multiplied by an emission factor that reflects the amount of the carbon content of the fuel stored in non-energy product (see ***Table III.1***). The result is the maximum amount of carbon that could potentially be sequestered if that amount of carbon were stored in the non-energy product. By subtracting this amount from the total carbon calculated in step 3, the amount of carbon that could be theoretically converted in CO_2 is calculated.

Step 5: Estimation of carbon unoxidised during fuel use.

The amount of carbon that was previously calculated is reduced by a fraction up to 2%, depending on fuel type, in order to take account of the fact that a small part of the fuel carbon entering combustion escapes oxidation (see ***Table 3.13***). It is assumed that the carbon that remains unoxidised is stored indefinitely.

Step 6: Estimation of CO_2 emissions.

Carbon emissions from all fuels are multiplied by 44/12 to be converted to CO_2 emissions. and are summed. giving the total amount of CO_2 released in the atmosphere.

As it was mentioned in Section 3.2. the net calorific value of lignite is differentiated on an annual basis according to the characteristics of the mining field from which it is extracted.

The application of the reference approach for 2019 is presented hereafter (Tables 1.A(b) of the Common Reporting Format).

Table III.1 Reference approach for 2023

FUEL TYPES			Unit	Production	Imports	Exports	International bunkers	Stock change	Apparent consumption	Conversion factor (TJ/Unit) (1)	NCV/ GCV (2)	Apparent consumption (TJ)	Carbon emission factor (t C/TJ)	Carbon content (kt)	Carbon stored (C excluded) (kt C)	Net carbon emissions ((kt) C)	Fraction of carbon oxidized	Actual CO_2 emissions ((kt) CO_2)
Liquid fossil	Primary fuels																	
		Crude oil	kt	50.79	23,331.44	125.80		-121.04	23,377.47	42.30	NCV	988,866.94	20.00	19,777.34	NO	19,777.34	1.00	72,516.91
		Natural gas liquids	kt	NO	NO	NO		NO	NO	41.56	NCV	NO	17.50	NO	NO	NO	1.00	NO
	Secondary fuels																	
		Gasoline	kt		43.51	4,817.23	NO	53.65	-4,827.37	42.79	NCV	-206,562.99	19.98	-4,126.92	NO	-4,126.92	1.00	-15,132.02
		Jet kerosene	kt		126.82	1,534.42	1,171.67	48.51	-2,627.77	44.10	NCV	-115,884.75	19.50	-2,259.75	NO	-2,259.75	1.00	-8,285.76
		Other kerosene	kt		0.65	6.81	NO	0.10	-6.25	43.80	NCV	-273.88	19.60	-5.37	NO	-5.37	1.00	-19.68
		Gas/diesel oil	kt		1,080.28	7,001.99	478.47	66.34	-6,466.52	42.78	NCV	-276,605.48	20.05	-5,545.03	NO	-5,545.03	1.00	-20,331.78
		Residual fuel oil	kt		1,828.29	1,699.68	1,584.24	-62.65	-1,392.98	40.58	NCV	-56,527.17	21.37	-1,208.00	NO	-1,208.00	1.00	-4,429.34
		Liquefied petroleum gases (LPG)	kt		55.07	180.83		-6.10	-119.66	47.30	NCV	-5,659.87	17.20	-97.35	NO	-97.35	1.00	-356.95
		Naphtha	kt		617.91	86.53		-16.65	548.02	44.50	NCV	24,387.02	20.00	487.74	NO	487.74	1.00	1,788.38
		Bitumen	kt		NO	1,624.05		19.83	-1,643.88	40.20	NCV	-66,083.86	22.00	-1,453.84	148.18	-1,602.02	1.00	-5,874.08
		Lubricants	kt		2.84	163.69	5.42	-3.52	-162.75	40.20	NCV	-6,542.43	20.00	-130.85	67.55	-198.40	1.00	-727.46
		Petroleum coke	kt		448.78	28.19		5.97	414.62	31.51	NCV	13,065.58	24.59	321.25	NO	321.25	1.00	1,177.92
		Refinery feedstocks	kt		3,836.48	NO		-257.98	4,094.46	43.00	NCV	176,061.78	20.00	3,521.24	NO	3,521.24	1.00	12,911.20
		Other oil	kt		3.29	562.72		3.95	-563.38	40.20	NCV	-22,647.80	20.00	-452.96	169.78	-622.74	1.00	-2,283.36
	Other liquid fossil (*please specify*)											NO						
Liquid fossil totals												445,593.11		8,827.50	385.51	8,442.00		30,953.98
Solid fossil	Primary fuels																	
		Anthracite(3)	kt	NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Coking coal	kt	NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Other bituminous coal	kt	NO	49.41	NO	NO	-36.49	85.89	24.17	NCV	2,076.28	26.34	54.70	NO	54.70	1.00	200.56
		Sub-bituminous coal	kt	NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Lignite	kt	10,770.68	NO	798.43		341.95	9,630.31	4.86	NCV	46,803.28	36.29	1,698.62	NO	1,698.62	0.98	6,103.70
	Secondary fuels																	
		BKB(4) and patent fuel	kt		NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
		Coke oven/gas coke	kt		NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	1.00	NO
		Coal tar			NO	NO		NO	NO	NO	NCV	NO	NO	NO	NO	NO	NO	NO
	Other solid fossil (*please specify*)											NO						
Solid fossil totals												48,879.56		1,753.32	NO	1,753.32		6,304.26
Gaseous fossil (5)																		
		Natural gas (dry)	TJ	109.04	171,798.48	9,438.15	NO	-3,876.86	166,346.22	1.00	NCV	166,346.22	15.22	2,531.25	122.74	2,408.51	1.00	8,831.22
Gaseous fossil totals												166,346.22		2,531.25	122.74	2,408.51		8,831.22
Waste (non-biomass fraction)				NO	NO	NO	NO	NO	NO	NO	NCV	NO	NO	NO		NO	NO	NO
Other fossil fuels *(please specify)*												NO						
Other fossil fuels totals												NO		NO		NO		NO
Peat(6,7)											NCV							NO
Total												660,818.89		13,112.07	508.25	12,603.83		46,089.46
Biomass total												43,629.15		1,202.31		1,202.31		4,408.47
		Solid biomass	TJ	36,361.55	610.25	156.13		NO	36,815.67	1.00	NCV	36,815.67	29.90	1,100.79		1,100.79	1.00	4,036.23
		Liquid biomass	TJ								NCV							
		Gas biomass		6,813.48	NO	NO	NO	NO	6,813.48	1.00	NCV	6,813.48	14.90	101.52		101.52	1.00	372.24
		Other non-fossil fuels (biogenic waste)		NO	NO	NO		NO	NO	NO	NCV	NO	NO	NO		NO	NO	NO

Annex IV: Uncertainty analysis

Uncertainty analysis constitutes a key activity in the annual inventory cycle. The realisation of such an analysis is foreseen in the reporting guidelines under the Convention and represents a specific function to be performed by a National System (Decision 24/CP.19).

Uncertainty information is not intended to dispute the validity of the inventory estimates, but to

Legend

help prioritize efforts to improve the accuracy of inventories and guide decisions on methodological choice. This will be achieved with the correct application of the analytic calculating methods at least for the key categories.

There are two methods for the uncertainty estimation suggested by the 2006 IPCC Guidelines. a basic method (Tier 1) which is mandatory and an analytic one (Tier 2).

The Tier 2 methodology is based on Monte Carlo analysis. The principle of Monte Carlo analysis is to select random values of emission factor and activity data from within their individual probability density functions, and to calculate the corresponding emission values. This procedure is repeated many times, and the results of each calculation run build up the overall emission probability density function. Monte Carlo analysis can be performed at the source category level, for aggregations of source categories or for the inventory as a whole. This analysis is suitable for a composite system such as the calculation of GHG emissions in national level. but its application requires significant resources and time.

The application of the Tier 1 methodology for uncertainty analysis is based on the following equations.

A. Uncertainty of total emissions

$$u_{i,g} = \sqrt{u_{AD,i}^2 + u_{EF,i,g}^2}$$

$$U_{i,g} = \frac{u_{i,g} \cdot E_{i,g}}{\sum_{i,g} E_{i,g}}$$

$$U_{tot} = \sqrt{\sum_{i,g} U_{i,g}^2}$$

where. i is the index referring to emission sources, g is the index referring to GHG, $u_{i.g}$ is the combined uncertainty for emissions of g-gas and i-source, $u_{AD.i}$ is the uncertainty of activity data of the i-source, $u_{EF.i.g}$ is the uncertainty of the emission factor of g-gas and i-source, $U_{i.g}$ is the uncertainty of the calculated emissions of g-gas and i-source, $E_{i.g}$ are the emissions of g-gas and i-source and U_{tot} is the uncertainty of total emissions. Uncertainty estimations on activity data ($u_{AD.i}$) and on the emission factors ($u_{EF.i.g}$) are based on IPCC defaults using expert judgement and

reasoning details and detailed explanation regarding their choice for each sector is presented in ***Table IV.1***.

B. Uncertainty in trend in emissions

$$A_{i,g} = \frac{0{,}01 \cdot E_{i,g,t} + \sum_{i,g} E_{i,g,t} - \left(0{,}01 \cdot E_{i,g,0} + \sum_{i,g} E_{i,g,0}\right)}{0{,}01 \cdot E_{i,g,0} + \sum_{i,g} E_{i,g,0}} \cdot 100 - \frac{\sum_{i,g} E_{i,g,t} - \sum_{i,g} E_{i,g,0}}{\sum_{i,g} E_{i,g,0}} \cdot 100$$

$$B_{i,g} = \frac{E_{i,g,t}}{\sum_{i,g} E_{i,g,0}}$$

$$TREF_{i,g} = A_{i,g} \cdot u_{EF,i,g}$$

$$TRAD_i = B_{i,g} \cdot u_{AD,i} \cdot \sqrt{2}$$

$$U_{TR} = \sqrt{\sum_{i,g} TREF_{i,g}^2 + TRAD_{i,g}^2}$$

where, t is the index referring to the inventory year, 0 is the index referring to the base year, $A_{i,g}$ is the difference (%) of emissions of g-gas and i-source in response to a 1% increase of emissions in the base year and inventory year, $E_{i,g,t}$ emissions of g-gas and i-source in the inventory year, $E_{i,g,0}$ emissions of g-gas and i-source in the base year, $B_{i,g}$ the difference (%) of emissions of g-gas and i-source in response to a 1% increase of emissions in the inventory year, $TREF_{i,g}$ the contribution of EF uncertainty of g-gas and i-source to the uncertainty in the trend of emissions, $TRAD_i$ the contribution of AD uncertainty i-source to the uncertainty in the trend of emissions and U_{TR} is the uncertainty in the trend of emissions.

The uncertainty analysis for the Greek GHG inventory is based on Tier 1 methodology with 1990 as base year for CO_2, CH_4, N_2O and F-gases emissions.

Moreover:

- For the estimation of uncertainties per gas, a combination of the information provided by the IPCC and critical evaluation of information from indigenous sources was applied.
- 100% of emissions are used for the uncertainty analysis.
- The uncertainty analysis was carried out both without and with the *LULUCF* sector.

In the ***Tables IV.2*** and ***IV.3***, the analytical calculations of the emissions estimates uncertainty are presented, without and with the sector of *LULUCF* respectively.

Table IV.1 Reasoning for activity data and emission factor uncertainty value

IPCC Source category	Gass	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Stationary Combustion - solid fuels	CO_2	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports are used for the calculation of EFs for the majority of fuels. According to IPCC guidelines the use of default carbon content per fuel corresponds to 95% confidence intervals and the % uncertainty is estimated < 5%. We estimate the EF uncertainty to be 3%.
Stationary Combustion - liquid fuels	CO_2	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports are used for the calculation of EFs for the majority of fuels. According to IPCC guidelines the use of default carbon content per fuel corresponds to 95% confidence intervals and the % uncertainty is estimated < 5%. We estimate the EF uncertainty to be 3%.
Stationary Combustion - gaseous fuels	CO_2	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports and CS data from DESFA are used for the calculation of EF of NG. We estimate the EF uncertainty to be 2%.
Stationary Combustion - Other fuels	CO_2	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	PS data from verified EU-ETS reports are used for the calculation of EFs for the majority of fuels. According to IPCC guidelines the use of default carbon content per fuel corresponds to 95% confidence intervals and the % uncertainty is estimated < 5%. We estimate the EF uncertainty to be 3%.
Road transport	CO_2	Default IPCC uncertainty is 5%.	Uncertainty of emissions of CO2 is 5% (IPCC default)
Navigation	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default uncertainty.
Civil Aviation	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default uncertainty.
Railway	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Other transportation	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default uncertainty.
Oil and Natural gas	CO_2	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	In IPCC GPG is mentioned that the EF used (from Table 2.16 p. 2.84) may be expected to limit uncertainties to within an order of magnitude. However. in order to be conservative. the value 300% is selected.
Cement Production	CO_2	Plant level production data (IPCC GPG).	Plant level production data (IPCC GPG)
Lime Production	CO_2	According to IPCC GPG is higher than EF's uncertainty.	IPCC default uncertainty.
Limestone & Dolomite Use	CO_2	Uncertainty of plant-level weighing of raw materials. Correction for LKD. CS assessment.	Stoichiometric EF. CS assessment.

IPCC Source category	Gass	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Glass Production	CO_2	Uncertainty associated with weighing or proportioning the carbonates for any given industry. Increased CS assessment in order to account for any missed non marketed products.	The emission factor is the stoichiometric ratio reflecting the amount of CO2 released upon calcination of the carbonate. CS assessment.
Ammonia Production	CO_2	Uncertainty of plant level weighting of glass production data. CS assessment.	Stoichiometric EF. CS assessment.
Other Chemicals (Hydrogen Production)	CO_2	Plant specific data (verified ETS reports)	Plant specific data (verifiedETS reports)
Iron and Steel Production	CO_2	Data obtained by the plant and therefore low uncertainty of AD is assumed.	Gaseous inputs and outputs have generally higher uncertainties than for solid or liquid inputs and outputs, so the E's uncertainty is a little higher than the one in the mineral production. CS assessment.
Ferroalloys	CO_2	Plant specific data (IPCC GPG)	The exact carbon content of all sources is reported. CS assessment.
Aluminium Production	CO_2	Detailed plant specific AD for years 2000-2008. Uncertainty is reported higher due to the estimation of the previous years. CS assessment.	Plant specific, source-specific carbon content availability for years 2000-2008. However the previous years have been estimated using the Ni production as a driver. CS assessment.
Waste incineration	CO_2	According to Good Practice Guidance. Page 5.30	According to Good Practice Guidance. Page 5.30
Forest Land remaining Forest Land	CO_2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Forest Land	CO_2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance and based on Italian NIR 2016.
Cropland remaining Cropland	CO_2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance, expert judgment based on country specific information
Conversion to Cropland	CO_2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance, expert judgment based on country specific information, and Italina NIR 2016
Grassland remaining grassland	CO2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance, expert judgment based on country specific information
Conversion to Grassland	CO2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance, expert judgment based on country specific information, and Italina NIR 2016
Conversion to Wetlands	CO2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Settlements	CO2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance, and Italina NIR 2016
Conversion to Other land	CO2	Expert judgment based on country specific information	Uncertainty from IPCC Guidance, and Italina NIR 2016
HWP	CO2	Uncertainty from IPCC Guidance	Uncertainty from IPCC Guidance

IPCC Source category	Gass	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
Stationary Combustion - all fuels	CH_4	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	Acc to Table 2.5 of IPCC GPG p 2.41 the default uncertainty for stationary combustion EF is 50-150%. We select the mean 100%.
Road transport	CH_4	Default IPCC uncertainty is 5%.	IPCC default
Navigation	CH_4	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Civil Aviation	CH_4	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Railway	CH_4	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Other transportation	CH_4	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Oil and Natural gas	CH_4	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	In IPCC GPG is mentioned that the EF used (from Table 2.16 p. 2.84) may be expected to limit uncertainties to within an order of magnitude. However. in order to be conservative. the value 300% is selected.
Coal Mining	CH_4	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range. Data are checked with plant level data from PPC. so the uncertainty is improved to 2%.	Acc to Table 2.14 of IPCC GPG p 2.77 the default uncertainty for surface Tier 1 methodology was used.
Organic chemicals production	CH_4	Values provided by the NSSG. CS assessment.	Use of default EF. CS assessment.
Iron and Steel Production	CH_4	Plant specific production data (IPCC GPG)	Default (SNAP 040207).
Enteric fermentation	CH_4	Uncertainty given by NSSG for the livestock population data	2006 IPCC Guidelines
Manure management	CH_4	Uncertainty given by NSSG for the livestock population data	2006 IPCC Guidelines.
Rice cultivation	CH_4	Uncertainty given by NSSG for the rice cultivation data	IPCC Rev. 1996. P. 4.58
Field burning of agr. Residues	CH_4	Uncertainty given by NSSG for the crop production data	According to Good Practice Guidance. Page 4.82. Table 4.22
Managed solid waste disposal	CH_4	Good Practice Guidance Page 5.12. Table 5.2 (Use of a multiplying factor of two on the suggested value)	2006 IPCC Guidelines
Unmanaged solid waste	CH_4	Good Practice Guidance Page 5.12. Table 5.2 (Use of a multiplying factor of two on the suggested value)	2006 IPCC Guidelines

IPCC Source category	Gass	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
disposal			
Municipal Sludge Disposal on Land	CH_4	Good Practice Guidance Page 5.12. Table 5.2 (Use of a multiplying factor of two on the suggested value)	2006 IPCC Guidelines
Wastewater handling	CH_4	According to Good Practice Guidance. Page 5.19 Table 5.3 and Page 5.23 Table 5.5	Uncertainty from IPCC Guidance
Waste incineration	CH_4	According to Good Practice Guidance. Page 5.30	2006 IPCC Guidelines and Country Specific
Forest Land remaining Forest Land	CH_4	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Forest land	CH_4	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Grassland remaining Grassland	CH_4	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Stationary Combustion - all fuels	N_2O	5% corresponds to the IPCC default uncertainty range for AD obtained from national energy balances. Since AD are cross-checked with PS AD from verified EU-ETS reports (source specific QA/QC), the uncertainty of AD is reduced to 3%.	Although in IPCC GPG is mentioned that EF from Table 2.16 may be expected to limit uncertainties to within an order of magnitude. in order to be conservative we select 300% as uncertainty.
Road transport	N_2O	Default IPCC uncertainty is 5%.	IPCC default.
Navigation	N_2O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default.
Civil Aviation	N_2O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default.
Railway	N_2O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default
Other transportation	N_2O	Activity data obtained from national energy balance. 5% corresponds to the IPCC default uncertainty range.	IPCC default.
Nitric Acid	N_2O	Plant specific data (IPCC GPG)	N2O may be generated as by product and the Nox abatement may or may note reduce N2O (IPCC GPG).
Manure management	N_2O	Country specific data taking into account that there is a wide variety of manure management systems and that the situation in Greece is not absolute clear.	Uncertainty from IPCC Guidance
Agricultural	N_2O	Uncertainty given by NSSG for the crop production	Uncertainty from IPCC Guidance

IPCC Source category	Gass	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
soils - direct emissions		data	
Agricultural soils - indirect emissions	N_2O	Uncertainty given by NSSG for the fertilizers consumption data	Uncertainty from IPCC Guidance
Animal Production	N_2O	Country specific data taking into account that there is a wide variety of manure management systems and that the situation in Greece is not absolute clear.	Uncertainty from IPCC Guidance
Field burning of agr. Residues	N_2O	Uncertainty given by NSSG for the crop production data	Uncertainty from IPCC Guidance
Wastewater handling	N_2O	According to Good Practice Guidance . Page 5.19 Table 5.3 and Page 5.23 Table 5.5	Uncertainty from IPCC Guidance
Waste incineration	N_2O	According to Good Practice Guidance. Page 5.30	Uncertainty from IPCC Guidance
Forest Land remaining Forest Land	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Forest Land	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Cropland	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Grassland remaining grassland	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Grassland	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Wetlands	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Settlements	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
Conversion to Other land	N_2O	Expert judgment based on country specific information	Uncertainty from IPCC Guidance
HFC-23 Emissions from HCFC-22 Manufacture	HFC	IPCC GPG: Tier 1. absolute knowledge of variability of emissions from different industries (1 plant).	IPCC GPG: Tier 1. absolute knowledge of variability of emissions from different industries (1 plant).
Refrigeration and Air Conditioning Equipment	HFC	Assumption on HFCs penetration	Expert judgement , in default range
Foam Blowing	HFC	IPCC GPG	IPCC GPG
Fire Extinguishers	HFC	Absence of data	Default value
Aerosols/MDIs	HFC	Data provided by National Organization of Medicine	Default values

IPCC Source category	Gass	Reasoning for activity data uncertainty	Reasoning for emission factor uncertainty
		and at a brand level.	
PFC from Aluminium	PFC	Plant specific data. measurements by plant.	give an overall guidance but are not updated each year."
SF6 from electrical equipment	SF6	Uncertainty of the values provided by PPC regarding the transmission system. CS assessment.	IPCC GPG default for use of SF_6.

Table IV.2 Uncertainty analysis without LULUCF

Reporting on uncertainty and completeness pursuant to Article 12

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty	Emission factor/estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data Note A	Input data Note A	$\sqrt{E^2 + F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	$I*F$ Note C	$J*E*\sqrt{2}$ Note D	
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
1.A Fuel Combustion Activities												
Liquid	CO2	35,621	32,191	3%	3%	0.0	0.0004	0.0724	0.3096	0.22%	1.31%	0.02%
Solid	CO2	38,912	6,227	3%	3%	0.0	0.0000	0.1982	0.0599	0.59%	0.25%	0.00%
Gas	CO2	102	8,769	3%	2%	0.0	0.0000	0.0837	0.0843	0.17%	0.36%	0.00%
Other fossil fuels	CO2	0	360	3%	3%	0.0	0.0000	0.0035	0.0035	0.01%	0.01%	0.00%
1.A.1 Energy Industry												
Liquid	CH4	8	7	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	14	11	3%	300%	3.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
Solid	CH4	8	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	115	19	3%	300%	3.0	0.0000	0.0006	0.0002	0.18%	0.00%	0.00%
Gas	CH4	0	3	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

	N2O	0	3	3%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
Biomass	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
1.A.2 Industries and Construction												
Liquid	CH4	6	2	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	25	24	3%	300%	3.0	0.0000	0.0001	0.0002	0.02%	0.00%	0.00%
Solid	CH4	1	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	15	1	3%	300%	3.0	0.0000	0.0001	0.0000	0.03%	0.00%	0.00%
Gas	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	1	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Other fossil fuels	CH4	0	2	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	3	3%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
Biomass	CH4	7	7	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	8	9	3%	300%	3.0	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
1.A.3 Transport												
a. Domestic aviation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	2	3	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
b. Road Transportation	CH4	120	61	4%	40%	0.4	0.0000	0.0002	0.0006	0.01%	0.00%	0.00%
	N2O	104	103	5%	50%	0.5	0.0000	0.0003	0.0010	0.01%	0.01%	0.00%
c. Railways	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	21	1	5%	300%	3.0	0.0000	0.0001	0.0000	0.04%	0.00%	0.00%
d. Domestic Navigation	CH4	3	4	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

	N2O	115	111	5%	300%	3.0	0.0000	0.0003	0.0011	0.09%	0.01%	0.00%
e. Other Transportation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
1.A.4 Other Sectors												
Liquid	CH4	12	3	3%	100%	1.0	0.0000	0.0001	0.0000	0.01%	0.00%	0.00%
	N2O	279	37	3%	300%	3.0	0.0000	0.0015	0.0004	0.45%	0.00%	0.00%
Solid	CH4	8	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Gas	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	1	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	CH4	247	260	3%	100%	1.0	0.0000	0.0009	0.0025	0.09%	0.01%	0.00%
	N2O	31	33	3%	300%	3.0	0.0000	0.0001	0.0003	0.03%	0.00%	0.00%
1.A.5 Other (Not specified elsewhere)												
	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	3	5%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
1B Coal Mining	CH4	1,266	263	2%	300%	3.0	0.0001	0.0059	0.0025	1.77%	0.01%	0.03%
1.B.2 Oil and Natural Gas	CO2	43	3	5%	300%	3.0	0.0000	0.0003	0.0000	0.08%	0.00%	0.00%
	CH4	41	124	5%	300%	3.0	0.0000	0.0009	0.0012	0.28%	0.01%	0.00%
	N2O	0	0	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2 Industrial Processes and Product Use												
2.A.1 Cement Production	CO2	5,762	2,998	2%	2%	0.0	0.0000	0.0095	0.0288	0.02%	0.08%	0.00%

2.A.2 Lime Production	CO2	404	150	5%	6%	0.1	0.0000	0.0012	0.0014	0.01%	0.01%	0.00%
2.A.3 Glass production	CO2	20	16	5%	3%	0.1	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
2.A.4 Other process uses of carbonates	CO2	590	216	10%	5%	0.1	0.0000	0.0018	0.0021	0.01%	0.03%	0.00%
2.B.1 Ammonia Production	CO2	652	148	3%	6%	0.1	0.0000	0.0029	0.0014	0.02%	0.01%	0.00%
2.B.2 Nitric acid production	N2O	948	7	2%	3%	0.0	0.0000	0.0062	0.0001	0.02%	0.00%	0.00%
2.B.8 Petrochemical and Carbon Black Production	CO2	29	0	5%	5%	0.1	0.0000	0.0002	0.0000	0.00%	0.00%	0.00%
	CH4	1	0	5%	5%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.B.10 Other-Hydrogen production	CO2	0	301	3%	3%	0.0	0.0000	0.0029	0.0029	0.01%	0.01%	0.00%
2.B.9 Flurochemical production	HFC	991	0	50%	50%	0.7	0.0000	0.0066	0.0000	0.33%	0.00%	0.00%
2.C.1 Iron and Steel Production	CO2	105	65	5%	5%	0.1	0.0000	0.0001	0.0006	0.00%	0.00%	0.00%
	CH4	0	0	5%	4%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.2 Ferroalloys	CO2	622	0	7%	7%	0.1	0.0000	0.0041	0.0000	0.03%	0.00%	0.00%
2.C.3 Aluminium Production	CO2	225	299	2%	2%	0.0	0.0000	0.0014	0.0029	0.00%	0.01%	0.00%
2.C.3 Aluminium Production	PFCs	171	64	3%	6%	0.1	0.0000	0.0005	0.0006	0.00%	0.00%	0.00%
2.C.4. Magnesium production	SF6	0	0	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.5 Lead production	CO2	14	8	2%	20%	0.2	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
2.C.6 Zinc production	CO2	46	41	2%	20%	0.2	0.0000	0.0001	0.0004	0.00%	0.00%	0.00%
2.D.1 Lubricant Use	CO2	78	50	5%	5%	0.1	0.0000	0.0000	0.0005	0.00%	0.00%	0.00%
2.D.2 Paraffin Wax Use	CO2	0	7	5%	5%	0.1	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
2.D.3 Emissions from the use of urea as a catalyst	CO2	52	15	3%	3%	0.0	0.0000	0.0002	0.0001	0.00%	0.00%	0.00%

2.G.4 Other product manufacture and use	CO2	102	88	5%	5%	0.1	0.0000	0.0002	0.0009	0.00%	0.01%	0.00%
2.F.1 Refrigeration and Air-Conditioning Equipment	HFC	0	4,171	100%	150%	1.8	0.0109	0.0401	0.0401	6.02%	5.67%	0.68%
	PFC	0	23	100%	150%	1.8	0.0000	0.0002	0.0002	0.03%	0.03%	0.00%
2.F.2 Foam Blowing	HFC	0	127	40%	50%	0.6	0.0000	0.0012	0.0012	0.06%	0.07%	0.00%
2.F.3 Fire Extinguishers	HFC	0	153	60%	10%	0.6	0.0000	0.0015	0.0015	0.01%	0.13%	0.00%
2.F.4 Aerosols	HFC	0	40	15%	5%	0.2	0.0000	0.0004	0.0004	0.00%	0.01%	0.00%
2.G.1 Electrical Equipment	SF6	3	5	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.G.3 N2O from Product Uses	N2O	119	120	5%	5%	0.1	0.0000	0.0004	0.0012	0.00%	0.01%	0.00%
3 Agriculture												
3.A Enteric Fermentation	CH4	4,603	4,120	5%	50%	0.5	0.0008	0.0090	0.0396	0.45%	0.28%	0.00%
3.B Manure Management	CH4	939	721	5%	30%	0.3	0.0000	0.0007	0.0069	0.02%	0.05%	0.00%
3.B Manure Management	N2O	335	268	5%	100%	1.0	0.0000	0.0003	0.0026	0.03%	0.02%	0.00%
3.C Rice Cultivation	CH4	92	117	2%	40%	0.4	0.0000	0.0005	0.0011	0.02%	0.00%	0.00%
3.D Direct N2O Emissions from Agricultural Soils	N2O	3,320	1,985	20%	200%	2.0	0.0031	0.0030	0.0191	0.60%	0.54%	0.01%
3.D Indirect N2O Emissions from Managed Soils	N2O	1,148	706	20%	50%	0.5	0.0000	0.0009	0.0068	0.04%	0.19%	0.00%
3.F Field burning of agricultural residues	CH4	30	17	20%	20%	0.3	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
	N2O	7	4	20%	20%	0.3	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
3.H Urea application	CO2	60	31	20%	50%	0.5	0.0000	0.0001	0.0003	0.01%	0.01%	0.00%
5 Waste												

5.A.1 Managed waste disposal sites	CH4	90	3,115	30%	30%	0.4	0.0003	0.0294	0.0300	0.88%	1.27%	0.02%
5.A.1 Unmanaged waste disposal sites	CH4	2,423	1,355	30%	30%	0.4	0.0001	0.0031	0.0130	0.09%	0.55%	0.00%
5.B.1 Biological treatment of solid waste-Composting	CH4	1	118	30%	100%	1.0	0.0000	0.0011	0.0011	0.11%	0.05%	0.00%
	N2O	0	5	30%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5. Incineration and open burning of waste	CO2	0	4	50%	40%	0.6	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH4	0	0	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5.D.1 Domestic Wastewater Treatment and Discharge	CH4	1,703	169	30%	30%	0.4	0.0000	0.0097	0.0016	0.29%	0.07%	0.00%
	N2O	244	249	30%	30%	0.4	0.0000	0.0008	0.0024	0.02%	0.10%	0.00%
5.D.2 Industrial Wastewater Treatment and Discharge	CH4	919	1,177	30%	30%	0.4	0.0000	0.0052	0.0113	0.16%	0.48%	0.00%
	N2O	5	7	100%	30%	1.0	0.0000	0.0000	0.0001	0.00%	0.01%	0.00%
Total		**103,985.69**	**71,934.07**				**0.0159**					**0.0078**
		$\sum C$	$\sum D$				$\sum H$					
					Percentage uncertainty in total inventory: $\sqrt{\sum H}$			12.6%		Trend uncertainty:	$\sqrt{\sum M}$	8.9%

Source: 2006 IPPC guidelines, Volume 1, Table 3.2 Approach 1 uncertainty calculation

Table IV.3 Uncertainty analysis with LULUCF

Reporting on uncertainty and completeness pursuant to Article 12

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year x emissions or removals	Activity data uncertainty	Emission factor/estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data Note A	Input data Note A	$\sqrt{E^2 + F^2}$	$\frac{(G*D)^2}{(\sum D)^2}$	Note B	$\left\lvert\frac{D}{\sum C}\right\rvert$	$I*F$ Note C	$J*E*\sqrt{2}$ Note D	K^2+L^2
		Gg CO_2 equivalent	Gg CO_2 equivalent	%	%	%		%	%	%	%	%
1.A Fuel Combustion Activities												
Liquid	CO2	35,621	32,191	3%	3%	0.0	0.0004	0.0827	0.3165	0.25%	1.34%	0.02%
Solid	CO2	38,912	6,227	3%	3%	0.0	0.0000	0.1932	0.0612	0.58%	0.26%	0.00%
Gas	CO2	102	8,769	3%	2%	0.0	0.0000	0.0856	0.0862	0.17%	0.37%	0.00%
Other fossil fuels	CO2	0	360	3%	3%	0.0	0.0000	0.0035	0.0035	0.01%	0.02%	0.00%
1.A.1 Energy Industry												0.00%
Liquid	CH4	8	7	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	14	11	3%	300%	3.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
Solid	CH4	8	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	115	19	3%	300%	3.0	0.0000	0.0006	0.0002	0.17%	0.00%	0.00%
Gas	CH4	0	3	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

	N2O	0	3	3%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
Biomass	CH4	0	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
1.A.2 Industries and Construction												
Liquid	CH4	6	2	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	25	24	3%	300%	3.0	0.0000	0.0001	0.0002	0.02%	0.00%	0.00%
Solid	CH4	1	0	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	15	1	3%	300%	3.0	0.0000	0.0001	0.0000	0.03%	0.00%	0.00%
Gas	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	1	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Other fossil fuels	CH4	0	2	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	3	3%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
Biomass	CH4	7	7	3%	100%	1.0	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
	N2O	8	9	3%	300%	3.0	0.0000	0.0000	0.0001	0.01%	0.00%	0.00%
1.A.3 Transport												
a. Domestic aviation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	2	3	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
b. Road Transportation	CH4	120	61	4%	40%	0.4	0.0000	0.0002	0.0006	0.01%	0.00%	0.00%
	N2O	104	103	5%	50%	0.5	0.0000	0.0003	0.0010	0.02%	0.01%	0.00%
c. Railways	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	21	1	5%	300%	3.0	0.0000	0.0001	0.0000	0.04%	0.00%	0.00%
d. Domestic Navigation	CH4	3	4	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%

	N2O	115	111	5%	300%	3.0	0.0000	0.0003	0.0011	0.10%	0.01%	0.00%
e. Other Transportation	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
1.A.4 Other Sectors												
Liquid	CH4	12	3	3%	100%	1.0	0.0000	0.0001	0.0000	0.01%	0.00%	0.00%
	N2O	279	37	3%	300%	3.0	0.0000	0.0015	0.0004	0.44%	0.00%	0.00%
Solid	CH4	8	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Gas	CH4	0	1	3%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	1	3%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
Biomass	CH4	247	260	3%	100%	1.0	0.0000	0.0009	0.0026	0.09%	0.01%	0.00%
	N2O	31	33	3%	300%	3.0	0.0000	0.0001	0.0003	0.04%	0.00%	0.00%
1.A.5 Other (Not specified elsewhere)												
	CH4	0	0	5%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	3	5%	300%	3.0	0.0000	0.0000	0.0000	0.01%	0.00%	0.00%
1B Coal Mining	CH4	1,266	263	2%	300%	3.0	0.0001	0.0057	0.0026	1.71%	0.01%	0.03%
1.B.2 Oil and Natural Gas	CO2	43	3	5%	300%	3.0	0.0000	0.0002	0.0000	0.07%	0.00%	0.00%
	CH4	41	124	5%	300%	3.0	0.0000	0.0010	0.0012	0.29%	0.01%	0.00%
	N2O	0	0	5%	300%	3.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2 Industrial Processes and Product Use									0.0000			
2.A.1 Cement Production	CO2	5,762	2,998	2%	2%	0.0	0.0000	0.0083	0.0295	0.02%	0.08%	0.00%

2.A.2 Lime Production	CO2	404	150	5%	6%	0.1	0.0000	0.0012	0.0015	0.01%	0.01%	0.00%
2.A.3 Glass production	CO2	20	16	5%	3%	0.1	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
2.A.4 Other process uses of carbonates	CO2	590	216	10%	5%	0.1	0.0000	0.0017	0.0021	0.01%	0.03%	0.00%
2.B.1 Ammonia Production	CO2	652	148	3%	6%	0.1	0.0000	0.0028	0.0015	0.02%	0.01%	0.00%
2.B.2 Nitric acid production	N2O	948	7	2%	3%	0.0	0.0000	0.0062	0.0001	0.02%	0.00%	0.00%
2.B.8 Petrochemical and Carbon Black Production	CO2	29	0	5%	5%	0.1	0.0000	0.0002	0.0000	0.00%	0.00%	0.00%
	CH4	1	0	5%	5%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.B.10 Other-Hydrogen production	CO2	0	301	3%	3%	0.0	0.0000	0.0030	0.0030	0.01%	0.01%	0.00%
2.B.9 Flurochemical production	HFC	991	0	50%	50%	0.7	0.0000	0.0065	0.0000	0.32%	0.00%	0.00%
2.C.1 Iron and Steel Production	CO2	105	65	5%	5%	0.1	0.0000	0.0000	0.0006	0.00%	0.00%	0.00%
	CH4	0	0	5%	4%	0.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.2 Ferroalloys	CO2	622	0	7%	7%	0.1	0.0000	0.0041	0.0000	0.03%	0.00%	0.00%
2.C.3 Aluminium Production	CO2	225	299	2%	2%	0.0	0.0000	0.0015	0.0029	0.00%	0.01%	0.00%
2.C.3 Aluminium Production	PFCs	171	64	3%	6%	0.1	0.0000	0.0005	0.0006	0.00%	0.00%	0.00%
2.C.4. Magnesium production	SF6	0	0	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.C.5 Lead production	CO2	14	8	2%	20%	0.2	0.0000	0.0000	0.0001	0.00%	0.00%	0.00%
2.C.6 Zinc production	CO2	46	41	2%	20%	0.2	0.0000	0.0001	0.0004	0.00%	0.00%	0.00%
2.D.1 Lubricant Use	CO2	78	50	5%	5%	0.1	0.0000	0.0000	0.0005	0.00%	0.00%	0.00%
2.D.2 Paraffin Wax Use	CO2	0	7	5%	5%	0.1	0.0000	0.0001	0.0001	0.00%	0.00%	0.00%
2.D.3 Emissions from the use of urea as a	CO2	52	15	3%	3%	0.0	0.0000	0.0002	0.0001	0.00%	0.00%	0.00%

catalyst												
2.G.4 Other product manufacture and use	CO2	102	88	5%	5%	0.1	0.0000	0.0002	0.0009	0.00%	0.01%	0.00%
2.F.1 Refrigeration and Air-Conditioning Equipment	HFC	0	4,171	100%	150%	1.8	0.0123	0.0410	0.0410	6.15%	5.80%	0.71%
	PFC	0	23	100%	150%	1.8	0.0000	0.0002	0.0002	0.03%	0.03%	0.00%
2.F.2 Foam Blowing	HFC	0	127	40%	50%	0.6	0.0000	0.0012	0.0012	0.06%	0.07%	0.00%
2.F.3 Fire Extinguishers	HFC	0	153	60%	10%	0.6	0.0000	0.0015	0.0015	0.02%	0.13%	0.00%
2.F.4 Aerosols	HFC	0	40	15%	5%	0.2	0.0000	0.0004	0.0004	0.00%	0.01%	0.00%
2.G.1 Electrical Equipment	SF6	3	5	50%	20%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
2.G.3 N2O from Product Uses	N2O	119	120	5%	5%	0.1	0.0000	0.0004	0.0012	0.00%	0.01%	0.00%
3 Agriculture												
3.A Enteric Fermentation	CH4	4,603	4,120	5%	50%	0.5	0.0009	0.0103	0.0405	0.52%	0.29%	0.00%
3.B Manure Management	CH4	939	721	5%	30%	0.3	0.0000	0.0009	0.0071	0.03%	0.05%	0.00%
3.B Manure Management	N2O	335	268	5%	100%	1.0	0.0000	0.0004	0.0026	0.04%	0.02%	0.00%
3.C Rice Cultivation	CH4	92	117	2%	40%	0.4	0.0000	0.0005	0.0011	0.02%	0.00%	0.00%
3.D Direct N2O Emissions from Agricultural Soils	N2O	3,320	1,985	20%	200%	2.0	0.0035	0.0022	0.0195	0.45%	0.55%	0.01%
3.D Indirect N2O Emissions from Managed Soils	N2O	1,148	706	20%	50%	0.5	0.0000	0.0006	0.0069	0.03%	0.20%	0.00%
3.F Field burning of agricultural residues	CH4	30	17	20%	20%	0.3	0.0000	0.0000	0.0002	0.00%	0.00%	0.00%
	N2O	7	4	20%	20%	0.3	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
3.H Urea application	CO2	60	31	20%	50%	0.5	0.0000	0.0001	0.0003	0.00%	0.01%	0.00%

4 LAND USE, LAND-USE CHANGE AND FORESTRY												
4.A.1 Forest Land remaining Forest Land	CO2	-1,310	-1,680	5%	33%	0.3	0.0001	0.0079	0.0165	0.26%	0.12%	0.00%
	CH4	53	473	11%	70%	0.7	0.0000	0.0043	0.0046	0.30%	0.07%	0.00%
	N2O	3	22	11%	70%	0.7	0.0000	0.0002	0.0002	0.01%	0.00%	0.00%
4.A.2 Conversion to Forest Land	CO2	0	-20	5%	113%	1.1	0.0000	0.0002	0.0002	0.02%	0.00%	0.00%
	CH4	0	3	11%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	11%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.B.1 Cropland remaining Cropland	CO2	-819	-1,216	12%	52%	0.5	0.0001	0.0066	0.0120	0.34%	0.20%	0.00%
4.B.2 Conversion to Cropland	CO2	52	17	10%	50%	0.5	0.0000	0.0002	0.0002	0.01%	0.00%	0.00%
	N2O	0	1	11%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.C.1 Grassland remaining Grassland	CO2	0	0	10%	50%	0.5	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH4	18	57	10%	70%	0.7	0.0000	0.0004	0.0006	0.03%	0.01%	0.00%
	N2O	1	4	10%	70%	0.7	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
4.C.2 Conversion to Grassland	CO2	0	-2,071	10%	50%	0.5	0.0002	0.0204	0.0204	1.02%	0.29%	0.01%
	N2O	0	0									
4.D.2 Land converted to Wetlands	CO2	0	53	10%	50%	0.5	0.0000	0.0005	0.0005	0.03%	0.01%	0.00%
	N2O	0	0									
4.E.2 Conversion to Settlements	CO2	50	117	10%	50%	0.5	0.0000	0.0008	0.0012	0.04%	0.02%	0.00%
	N2O	0	6									
4.F.2 Conversion to Other Land	CO2	20	88	10%	50%	0.5	0.0000	0.0007	0.0009	0.04%	0.01%	0.00%

	N2O	0	7									
4.G Harvested Wood Products	CO2	-349	27	10%	50%	0.5	0.0000	0.0026	0.0003	0.13%	0.00%	0.00%
5 Waste												
5.A.1 Managed waste disposal sites	CH4	90	3,115	30%	30%	0.4	0.0004	0.0300	0.0306	0.90%	1.30%	0.03%
5.A.1 Unmanaged waste disposal sites	CH4	2,423	1,355	30%	30%	0.4	0.0001	0.0026	0.0133	0.08%	0.57%	0.00%
5.B.1 Biological treatment of solid waste-Composting	CH4	1	118	30%	100%	1.0	0.0000	0.0012	0.0012	0.12%	0.05%	0.00%
	N2O	0	5	30%	100%	1.0	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5. Incineration and open burning of waste	CO2	0	4	50%	40%	0.6	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	CH4	0	0	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
	N2O	0	0	50%	100%	1.1	0.0000	0.0000	0.0000	0.00%	0.00%	0.00%
5.D.1 Domestic Wastewater Treatment and Discharge	CH4	1,703	169	30%	30%	0.4	0.0000	0.0095	0.0017	0.29%	0.07%	0.00%
	N2O	244	249	30%	30%	0.4	0.0000	0.0008	0.0024	0.03%	0.10%	0.00%
5.D.2 Industrial Wastewater Treatment and Discharge	CH4	919	1,177	30%	30%	0.4	0.0001	0.0055	0.0116	0.17%	0.49%	0.00%
	N2O	5	7	100%	30%	1.0	0.0000	0.0000	0.0001	0.00%	0.01%	0.00%
Total		**101706.0723**	**67822.5072**				**0.0183**					**0.0083**
												ΣM

		$\sum C$	$\sum D$		Percentage uncertainty in total inventory:	$\sum H$	13.5%		Trend uncertainty:	$\sqrt{\sum M}$	9.1%

Source: 2006 IPPC guidelines, Volume 1, Table 3.2 Approach 1 uncertainty calculation

Legend

A: IPCC Source category
B: Gas
C: Base year emissions 1990
D: Year t emissions
E: Activity data uncertainty
F: Emission factor uncertainty
G: Combined uncertainty
H: Combined uncertainty as % of total national emissions in year t
I: Type A sensitivity
J: Type B sensitivity
K: Uncertainty in trend in national emissions introduced by emission factor uncertainty
L: Uncertainty in trend in national emissions introduced by activity data uncertainty
M: Uncertainty introduced into the trend in total national emissions

Annex V: Indirect greenhouse gases and SO_2

Nitrogen oxides

Emissions of nitrogen oxides in 2023 decreased by 32.65% compared to 1990 levels. Emissions of NOx derive by 96.7% from the energy sector and especially from transport, which is responsible for the 55.36 of total NOx emissions. In Table V.1 NOx emissions by source category for the period 1990 – 2023 are presented.

Carbon monoxide

Emissions of carbon monoxide in 2023 decreased by 55.41% approximately compared to 1990 levels. CO emissions derive by 66.14% from the energy sector and especially from transport, which is responsible for the 28.25% of total CO emissions. In Table V.2 CO emissions by source category for the period 1990 – 2023 are presented.

Non-methane volatile organic compounds

NMVOC emissions decreased by 49.93% in 2023 compared to 1990. NMVOC emissions derive by 41.49% from the energy sector and especially from transport, which is responsible for the 19.82% of total NMVOC emissions and 59.20% from the IPPU sector. In Table V.3 NMVOC emissions by source category for the period 1990 – 2023 are presented.

Sulphur dioxide

Sulphur dioxide emissions in 2023 decreased by 85.72% compared to 1990 levels. SO2 emissions derive by 95.43% from the energy sector and mainly from the energy industries, which are responsible for the 47.92% of total SO2 emissions. In Table V.4 SO2 emissions by source category for the period 1990 – 2023 are presented.

The operation of desulphurisation plants at large power plants since 1998 and the increasing share of RES technologies for electricity production resulted in the reduction of SO2 emissions from electricity generation. Reductions with respect to the sulphur content of liquid fossil fuels and the introduction of natural gas in the Greek energy system resulted in a reduction of SO2 emissions from manufacturing industry, transport and residential sectors.

Table V.1a NOx emissions (in kt) by source category for the period 1990 – 2008

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
TOTAL	**315.7**	**325.7**	**333.6**	**330.2**	**339.3**	**320.1**	**323.6**	**337.2**	**361.9**	**358.5**	**351.2**	**372.6**	**370.7**	**381.0**	**387.1**	**400.5**	**402.1**	**406.0**	**383.3**
Energy	**312.6**	**323.1**	**330.7**	**327.2**	**336.6**	**317.7**	**321.2**	**334.7**	**358.4**	**356.3**	**347.1**	**370.5**	**368.7**	**379.0**	**385.0**	**398.5**	**400.1**	**401.0**	**381.1**
Fuel combustion	164.9	173.7	180.7	174.1	181.4	169.5	170.8	182.0	204.3	201.2	191.2	212.8	364.3	374.4	380.5	394.1	395.5	396.4	376.8
Energy industries	73.0	79.3	88.4	86.2	91.7	81.5	84.5	89.8	94.3	93.9	104.0	114.1	116.4	124.6	131.6	145.5	138.7	148.9	140.6
Industry	20.2	20.4	19.8	19.0	18.7	20.8	22.3	22.5	22.2	20.1	21.5	21.5	20.4	19.7	18.3	21.1	21.7	20.9	19.7
Transport	180.5	182.7	184.0	184.9	188.2	179.0	176.2	184.3	203.8	204.9	183.3	195.3	189.8	189.4	194.5	187.7	193.2	188.5	179.4
Other sectors	35.4	37.7	35.2	34.4	34.6	32.8	33.9	33.7	33.7	33.6	33.7	35.0	37.7	40.7	36.2	37.6	39.2	35.9	34.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.7	2.3	2.9
Fugitive emissions	3.5	3.1	3.2	2.7	3.4	3.6	4.3	4.4	4.4	3.9	4.7	4.6	4.4	4.6	4.5	4.5	4.5	4.6	4.3
Industrial processes	**1.5**	**1.3**	**1.1**	**1.2**	**1.1**	**1.1**	**1.2**	**1.1**	**1.1**	**1.2**	**1.1**	**0.9**	**1.1**	**1.1**	**1.1**	**1.0**	**0.9**	**1.0**	**1.0**
Chemical industry	1.1	0.9	0.8	0.9	0.8	0.8	0.9	0.8	0.7	0.8	0.7	0.5	0.7	0.7	0.6	0.5	0.4	0.4	0.4
Metal Industry	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5
Other	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	**1.0**	**1.0**	**1.0**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.9**	**0.8**	**0.9**
LULUCF																			

Table V.1b NOx emissions (in kt) by source category for the period 2009 – 2023

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TOTAL	**371.3**	**314.8**	**292.5**	**242.9**	**242.3**	**236.1**	**232.9**	**229.7**	**250.2**	**240.7**	**237.7**	**207.6**	**207.9**	**222.0**	**212.6**
Energy	**369.2**	**312.9**	**290.6**	**241.0**	**240.6**	**234.5**	**231.4**	**228.1**	**248.5**	**239.1**	**235.5**	**206.0**	**205.2**	**220.1**	**205.7**
Fuel combustion	365.0	308.3	286.7	236.1	235.9	229.6	226.2	222.6	242.8	233.2	230.0	200.7	199.5	215.2	200.1
Energy industries	129.8	120.3	119.0	108.6	96.8	92.3	88.9	84.0	91.2	84.5	76.2	62.5	62.2	64.2	59.7
Industry	15.9	14.5	10.6	11.2	10.1	10.7	10.4	10.5	19.0	16.4	15.0	13.3	13.1	15.9	12.8
Transport	191.1	147.8	129.7	100.8	116.6	115.2	114.5	116.9	121.9	121.8	128.2	109.9	112.5	121.9	117.7
Other sectors	27.2	24.6	26.4	14.6	11.4	10.5	11.5	10.3	9.9	10.0	9.9	13.7	11.5	11.9	10.0
Other	1.0	1.0	0.9	0.9	1.0	0.8	0.9	0.8	0.8	0.5	0.6	1.2	0.1	1.3	1.3
Fugitive emissions	4.1	4.7	4.0	4.9	4.8	5.0	5.2	5.6	5.8	5.8	5.5	5.3	5.7	5.3	5.6
Industrial processes	**0.8**	**0.9**	**0.9**	**0.7**	**0.7**	**0.8**	**0.8**	**0.6**	**0.9**	**0.8**	**0.8**	**0.8**	**0.8**	**0.9**	**0.7**
Chemical industry	0.4	0.4	0.5	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3
Metal Industry	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3
Other	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Agriculture	**0.9**	**0.8**	**0.8**	**0.8**	**0.8**	**0.7**	**0.6**	**0.6**	**0.7**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
LULUCF															

Table V.2a CO emissions (in kt) by source category for the period 1990 – 2008

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
TOTAL	1,270.4	1,233.0	1,200.8	1,197.6	1,175.8	1,086.8	1,082.4	1,092.5	1,128.0	1,063.5	1,092.4	1,026.0	974.3	941.3	921.2	869.9	892.9	944.4	753.3
Energy	1,227.4	1,200.8	1,147.4	1,148.3	1,129.8	1,053.1	1,054.9	1,053.3	1,052.1	1,037.3	997.0	993.4	949.0	915.3	891.9	841.2	860.5	806.5	713.0
Fuel combustion	354.3	356.6	352.3	347.9	347.2	357.0	364.5	366.9	366.2	354.6	360.5	360.8	947.3	913.6	890.2	839.6	858.8	804.8	711.3
Energy industries	21.0	20.6	21.6	21.6	22.5	22.0	21.6	23.1	24.0	24.0	25.8	25.9	25.6	26.3	26.6	27.0	25.7	27.0	26.6
Industry	109.6	110.4	107.1	103.2	101.4	112.5	120.7	121.1	116.8	105.3	112.0	111.4	105.2	101.1	92.6	107.0	110.4	106.1	98.9
Transport	877.6	848.6	799.6	804.9	787.1	700.1	693.7	690.6	692.5	689.5	640.3	637.7	598.6	577.6	565.3	499.7	517.6	453.7	404.1
Other sectors	218.0	220.0	217.8	217.6	217.6	217.0	217.3	217.0	217.2	217.1	217.1	216.6	218.0	208.6	205.7	205.1	204.2	217.2	180.8
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.9	0.8	1.0
Fugitive emissions	1.3	1.2	1.2	1.0	1.3	1.3	1.6	1.6	1.7	1.4	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.6
Industrial processes	**19.9**	**20.1**	**20.1**	**19.5**	**18.1**	**17.5**	**17.2**	**17.8**	**19.6**	**21.0**	**21.6**	**21.8**	**22.9**	**23.1**	**23.5**	**23.9**	**24.1**	**24.4**	**24.0**
Chemical industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal Industry	19.7	20.0	20.0	19.4	18.0	17.3	17.1	17.7	19.4	20.8	21.4	21.6	22.8	22.9	23.3	23.7	23.9	24.3	23.9
Non-energy Products from Fuels and Solvent Use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	**1.2**	**1.2**	**1.2**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**	**1.0**	**1.0**	**1.0**	**1.0**
LULUCF																			

Table V.2b CO emissions (in kt) by source category for the period 2009 – 2023

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TOTAL	**686.3**	**610.1**	**595.3**	**669.2**	**548.0**	**555.2**	**530.1**	**477.7**	**469.5**	**442.8**	**451.9**	**398.5**	**440.8**	**426.6**	**566.4**
Energy	**650.0**	**583.7**	**564.9**	**630.9**	**519.2**	**528.3**	**502.2**	**442.0**	**437.5**	**410.4**	**399.6**	**366.1**	**367.1**	**381.3**	**374.6**
Fuel combustion	648.4	581.9	563.4	629.0	517.4	526.4	500.3	439.9	435.4	408.2	397.5	364.1	365.0	379.3	372.5
Energy industries	24.9	21.8	22.1	18.3	16.5	16.6	15.0	12.9	31.3	30.3	24.3	15.9	16.2	15.3	12.7
Industry	78.7	71.4	49.8	49.9	44.1	49.2	47.4	48.5	5.9	6.4	7.0	7.0	7.2	7.8	7.3
Transport	383.6	324.8	293.9	261.8	245.1	267.6	236.1	203.2	204.8	194.8	191.5	172.4	166.0	165.9	160.0
Other sectors	160.9	163.7	197.4	298.6	211.3	192.8	201.4	175.0	193.0	176.6	174.4	168.4	175.6	189.9	192.5
Other	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.4	0.0	0.4	0.4
Fugitive emissions	1.5	1.7	1.5	1.8	1.8	1.9	2.0	2.1	2.2	2.2	2.1	2.0	2.1	2.0	2.1
Industrial processes	**19.1**	**19.7**	**23.3**	**22.1**	**22.4**	**22.7**	**23.4**	**23.9**	**24.7**	**24.9**	**24.4**	**25.1**	**25.0**	**25.3**	**24.4**
Chemical industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal Industry	19.0	19.5	23.1	22.0	22.2	22.5	23.2	23.7	24.5	24.7	24.2	24.9	24.8	25.0	24.2
Non-energy Products from Fuels and Solvent Use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
Agriculture	**1.1**	**1.0**	**0.9**	**0.9**	**0.8**	**0.9**	**0.8**	**0.8**	**0.8**	**0.7**	**0.7**	**0.7**	**0.7**	**0.6**	**0.7**
LULUCF															

Table V.3a NMVOC emissions (in kt) by source category for the period 1990 – 2008

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
TOTAL	**267.5**	**268.7**	**263.4**	**262.7**	**262.8**	**250.1**	**255.7**	**254.9**	**258.0**	**259.5**	**251.2**	**251.6**	**245.9**	**248.5**	**243.9**	**237.8**	**233.8**	**228.4**	**204.9**
Energy	**201.1**	**200.0**	**195.0**	**195.0**	**194.2**	**185.3**	**187.0**	**187.4**	**188.6**	**186.5**	**176.7**	**175.9**	**170.6**	**163.0**	**158.1**	**151.4**	**146.7**	**138.3**	**124.8**
Fuel combustion	45.0	45.6	44.7	44.2	44.5	45.4	46.8	47.3	47.9	46.3	47.9	48.3	145.5	137.9	132.8	125.4	121.6	112.3	99.4
Energy industries	7.3	7.4	7.1	7.2	7.6	7.8	8.3	8.5	8.6	8.1	9.5	9.6	9.8	9.6	9.8	10.9	9.5	6.5	5.3
Industry	12.4	12.5	12.2	11.9	11.6	12.7	13.6	13.7	13.4	12.4	13.4	13.3	12.9	12.0	11.3	13.1	13.2	12.8	12.6
Transport	139.2	137.5	132.8	133.5	131.5	120.7	120.1	120.1	120.7	120.3	107.1	105.7	99.2	94.2	90.2	79.6	77.2	70.4	61.9
Other sectors	23.5	23.9	23.4	23.4	23.4	23.2	23.3	23.2	23.3	23.2	23.3	23.2	23.6	22.1	21.4	21.4	21.3	22.2	19.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.4	0.5
Fugitive emissions	18.8	18.7	19.3	19.0	20.1	20.9	21.7	21.9	22.6	22.5	23.5	24.1	25.2	25.1	25.3	26.0	25.2	26.0	25.4
Industrial processes	**66.4**	**68.7**	**68.4**	**67.7**	**68.6**	**64.8**	**68.7**	**67.4**	**69.3**	**73.0**	**74.5**	**75.7**	**75.3**	**85.5**	**85.8**	**86.4**	**87.0**	**90.1**	**80.1**
Chemical industry	0.9	1.0	0.9	1.1	1.1	1.1	1.3	1.4	1.4	1.1	1.0	0.9	0.9	0.9	1.1	1.0	0.9	0.6	0.0
Metal Industry	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Non-energy Products from Fuels and Solvent Use	25.0	25.7	26.4	26.5	29.5	28.3	28.8	30.9	32.2	33.4	35.2	37.2	37.2	47.1	45.9	46.0	47.6	50.6	42.9
Other Product Manufacture and Use	36.3	37.9	36.7	35.7	33.8	31.2	34.5	31.2	31.6	34.5	34.0	33.2	32.8	33.6	34.7	35.2	34.2	34.7	33.3
Other	4.1	4.2	4.3	4.4	4.3	4.1	4.1	3.9	4.1	4.0	4.4	4.4	4.3	3.9	4.0	4.0	4.3	4.2	3.8

Table V.3b NMVOC emissions (in kt) by source category for the period 2009 – 2023

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TOTAL	**191.2**	**180.6**	**173.1**	**174.0**	**165.7**	**164.4**	**164.3**	**153.9**	**156.2**	**155.1**	**148.0**	**140.9**	**134.2**	**135.4**	**133.9**
Energy	**118.4**	**103.0**	**96.4**	**106.2**	**95.0**	**93.4**	**90.1**	**81.2**	**80.9**	**77.9**	**69.4**	**61.6**	**54.9**	**56.1**	**54.6**
Fuel combustion	93.3	79.9	74.1	83.1	74.4	73.7	71.2	64.9	61.2	58.5	53.1	49.1	47.9	49.1	48.0
Energy industries	5.7	5.4	5.6	6.3	5.7	5.9	5.7	5.9	8.2	7.9	3.5	2.6	2.7	2.8	2.4
Industry	10.4	9.8	7.9	7.4	6.0	6.7	6.9	6.5	2.5	2.8	2.7	3.0	2.4	2.4	2.4
Transport	60.0	47.8	41.7	36.9	42.6	43.7	40.4	36.8	33.8	32.1	31.7	28.4	27.2	27.3	26.5
Other sectors	17.1	16.9	18.8	32.3	19.9	17.2	18.0	15.6	16.5	15.6	15.2	15.0	15.6	16.4	16.6
Other	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.0	0.2	0.2
Fugitive emissions	25.1	23.1	22.2	23.1	20.6	19.8	18.9	16.4	19.7	19.4	16.3	12.4	7.1	7.0	6.7
Industrial processes	**72.8**	**77.6**	**76.8**	**67.7**	**70.7**	**71.0**	**74.2**	**72.6**	**75.3**	**77.2**	**78.6**	**79.3**	**79.3**	**79.3**	**79.3**
Chemical industry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metal Industry	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Non-energy Products from Fuels and Solvent Use	38.2	40.1	39.8	33.6	35.1	36.0	38.7	36.7	38.9	39.6	40.2	40.6	40.7	41.0	41.2
Other Product Manufacture and Use	30.7	33.2	32.4	30.4	31.1	29.9	30.4	30.6	30.9	32.0	32.5	32.6	33.1	33.4	33.7
Other	3.7	4.2	4.5	3.6	4.5	5.0	5.1	5.3	5.3	5.6	5.8	6.0	5.4	4.9	4.3

Table V.4a ***SO_2 emissions (in kt) by source category for the period 1990 – 2008***

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
TOTAL	**492.2**	**483.9**	**498.5**	**487.9**	**505.2**	**509.4**	**509.7**	**542.2**	**565.9**	**551.0**	**559.8**	**570.6**	**557.8**	**564.8**	**565.3**	**585.1**	**545.0**	**529.5**	**457.9**
Energy	**483.9**	**476.0**	**491.4**	**481.3**	**498.3**	**501.7**	**502.0**	**534.1**	**557.9**	**542.9**	**552.5**	**563.4**	**550.5**	**557.4**	**557.8**	**577.7**	**538.5**	**522.9**	**451.8**
Fuel combustion	474.9	468.1	483.1	474.3	489.6	492.5	490.8	522.8	546.4	532.9	540.5	551.6	539.0	545.5	546.2	566.1	526.8	511.0	440.6
Energy industries	333.6	325.3	342.4	342.1	356.7	348.2	342.1	367.1	381.0	374.9	401.7	405.6	399.7	407.5	414.2	422.3	390.9	396.2	351.6
Industry	112.4	113.7	110.6	106.1	104.4	116.2	124.2	124.9	120.2	109.4	115.2	114.8	109.1	105.9	94.9	110.3	99.8	82.4	61.6
Transport	38.7	38.7	41.0	38.2	42.7	32.1	30.6	37.7	52.6	56.4	21.3	28.7	25.1	26.7	31.7	27.8	30.4	27.4	23.3
Other sectors	9.0	9.6	9.1	8.9	7.4	7.3	5.4	5.1	5.1	5.2	5.0	5.4	5.2	5.5	5.5	5.8	5.7	5.0	4.1
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fugitive emissions	8.9	8.0	8.3	6.9	8.7	9.2	11.1	11.3	11.5	10.0	12.0	11.8	11.4	11.9	11.6	11.5	11.7	11.9	11.1
Industrial processes	**8.3**	**7.9**	**7.1**	**6.6**	**7.0**	**7.8**	**7.8**	**8.0**	**8.0**	**8.1**	**7.3**	**7.2**	**7.3**	**7.4**	**7.5**	**7.4**	**6.5**	**6.5**	**6.2**
Chemical industry	3.6	3.2	2.4	2.1	2.4	2.9	2.9	3.1	3.1	3.2	2.1	2.0	2.2	2.2	2.3	2.0	1.2	1.2	1.1
Metal Industry	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.3	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.4
Other	0.3	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table V.4b *SO_2 emissions (in kt) by source category for the period 2009 – 2023*

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
TOTAL	**410.8**	**231.0**	**168.2**	**142.0**	**130.5**	**114.5**	**112.1**	**107.4**	**105.5**	**99.1**	**88.8**	**71.1**	**74.5**	**77.2**	**70.3**
Energy	**406.0**	**226.1**	**164.2**	**138.1**	**126.1**	**109.8**	**107.9**	**102.9**	**101.1**	**94.7**	**84.5**	**67.2**	**70.5**	**73.3**	**67.1**
Fuel combustion	395.4	214.0	153.9	125.4	113.8	97.0	94.4	88.5	86.2	79.7	70.3	53.4	55.7	59.7	52.6
Energy industries	310.0	175.7	124.6	98.2	88.3	71.0	65.6	59.2	61.3	59.1	49.5	35.6	37.5	39.4	33.7
Industry	35.6	24.3	14.9	14.4	12.8	13.5	14.6	15.0	10.1	5.0	4.6	3.9	3.6	4.2	3.5
Transport	46.7	11.2	11.2	8.4	9.3	9.4	11.2	11.6	11.9	12.8	13.1	10.6	11.7	12.8	12.9
Other sectors	3.1	2.8	3.3	4.4	3.3	3.0	3.0	2.7	2.9	2.7	3.0	3.3	2.9	3.4	2.5
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fugitive emissions	10.6	12.0	10.2	12.7	12.3	12.8	13.5	14.4	14.9	15.1	14.3	13.8	14.7	13.6	14.5
Industrial processes	**4.7**	**4.9**	**4.1**	**3.8**	**4.4**	**4.7**	**4.2**	**4.4**	**4.5**	**4.4**	**4.2**	**3.9**	**4.0**	**3.9**	**3.2**
Chemical industry	0.9	1.2	1.1	0.5	0.6	0.8	0.6	0.6	0.7	0.7	0.6	0.6	0.6	0.6	0.0
Metal Industry	1.1	1.2	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.4	1.3	1.3	1.2	1.2
Other	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3