ISPRA
Istituto Superiore per la Protezione e la Ricerca Ambientale

Sistema Nazionale per la Protezione dell'Ambiente

Italian Emission Inventory 1990 – 2023. Informative Inventory Report 2025

RAPPORTI
410/2025

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ISPRA, Rapporti 410/25
ISBN 978-88-448-1251-5

Graphic design
Cover design: Alessia Marinelli – Ispra – Area Comunicazione
Cover image: graphic processing from an image generated with Stable Diffusion on the Wowzer platform by Angela Fiore e Luisa Mortola

Coordination of the online publication:
Daria Mazzella

ISPRA – Area Comunicazione

Aprile, 2025

Annual Report for submission under the UNECE Convention on Long-range Transboundary Air Pollution and European Union National Emission Ceiling Directive

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EXECUTIVE SUMMARY

The Italian Informative Inventory Report (IIR) is edited in the framework of the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution (CLRTAP). It contains information on the Italian inventory, including an explanation of methodologies, data sources, QA/QC activities and verification processes carried out during the inventory compilation, with an analysis of emission trends and a description of key categories.

The aim of the document is to facilitate understanding of the calculation of the Italian air pollutant emission data, hence providing a common mean for comparing the relative contribution of different emission sources and supporting the identification of reduction policies.

The Institute for Environmental Protection and Research (ISPRA) has the overall responsibility for the emission inventory submission to CLRTAP, as well as to the United Nations Framework Convention on Climate Change (UNFCCC) and oversees all the work related to inventory compilation.

In particular, in compliance with the LRTAP Convention, Italy has to submit annually data on national emissions of SO_X, NO_X, NMVOC, CO and NH_3, particulate matter and various heavy metals and POPs. The submission consists of the national emission inventory, communicated through compilation of the Nomenclature For Reporting (NFR), and the informative inventory report (IIR) to ensure the properties of transparency, consistency, comparability, completeness and accuracy.

In the period 1990-2023, emissions from almost all the pollutants described in this report show a downward trend. Reductions are especially relevant for the main pollutants (SO_X -96%; NO_X -74%; CO -73%; NMVOC -57%), for BC (-64%), cadmium (-62%), mercury (-65%), lead (-95%) and hexachlorobenzene (-92%). The major drivers for the trend are reductions in the industrial and road transport sectors, due to the implementation of various European Directives which introduced new technologies, plant emission limits, the limitation of sulphur content in liquid fuels and the shift to cleaner fuels. Emissions have also decreased for the improvement of energy efficiency as well as the promotion of renewable energy.

The energy sector is the main source of emissions in Italy with a share of more than 80%, including fugitive emissions, for many pollutants (SO_X 92%; NO_X 91%; CO 92%; PM2.5 84%; BC 89%; PAH 86%, HCB 91%). The industrial processes sector is an important source of emissions specifically related to the iron and steel production, at least for particulate matter, heavy metals and POPs, whereas significant emissions of SO_X derive from carbon black and sulphuric acid production; on the other hand, the solvent and other product use sector is characterized by NMVOC emissions. The agriculture sector is the main source of NH_3 emissions in Italy with a share of 91% in national total. Finally, the waste sector, specifically waste incineration, is a relevant source for BC (10%), Cd (10%), HCB (9%) and dioxins (17%).

Emission figures of the Italian emission inventory and other related documents are publicly available at https://emissioni.sina.isprambiente.it/inventario-nazionale/ .

SOMMARIO (Italiano)

L'*Informative Inventory Report* (IIR) è redatto nel quadro della Convenzione UNECE (*United Nations Economic Commission for Europe*) sull'inquinamento atmosferico transfrontaliero a lunga distanza (CLRTAP). Contiene informazioni sull'inventario italiano, compresa una spiegazione delle metodologie, delle fonti dei dati, delle attività di QA/QC e dei processi di verifica effettuati durante la compilazione dell'inventario, con un'analisi dell'andamento delle emissioni e una descrizione delle principali categorie.

Lo scopo del documento è quello di facilitare la comprensione delle metodologie per la stima delle emissioni degli inquinanti atmosferici in Italia, fornendo così uno strumento comune per confrontare il contributo relativo delle diverse fonti di emissione e supportare l'individuazione di politiche di riduzione.

L'Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA) ha la responsabilità generale della presentazione dell'inventario delle emissioni al CLRTAP, nonché alla Convenzione quadro delle Nazioni Unite sui cambiamenti climatici (UNFCCC) ed è responsabile di tutto il lavoro relativo alla compilazione dell'inventario.

In particolare, in ottemperanza alla Convenzione LRTAP, l'Italia deve presentare annualmente i dati sulle emissioni nazionali di SO_X, NO_X, NMVOC, CO e NH_3, e vari metalli pesanti e POP. La *submission* è costituita dall'inventario nazionale delle emissioni, comunicato attraverso la compilazione del Nomenclature For Reporting (NFR) e dal presente rapporto (IIR) per garantire le proprietà di trasparenza, coerenza, comparabilità, completezza e accuratezza.

Nel periodo 1990-2023, le emissioni di quasi tutti gli inquinanti descritti in questo rapporto mostrano una tendenza al ribasso. Le riduzioni sono particolarmente rilevanti per i principali inquinanti (SO_X -96%; NO_X -74%; CO -73%; NMVOC -57%), per BC (-64%), cadmio (-62%), mercurio (-65%), piombo (-95%) ed esaclorobenzene (-92%). I principali *driver* del *trend* sono costituiti dalle riduzioni nei settori industriale e del trasporto su strada, dovute all'implementazione di diverse Direttive Europee che hanno introdotto nuove tecnologie, più stringenti limiti di emissione degli impianti, limitazioni del contenuto di zolfo nei combustibili liquidi e quindi il passaggio a combustibili più puliti. Altri fattori determinanti per la riduzione delle emissioni sono stati il miglioramento dell'efficienza energetica e la promozione delle energie rinnovabili.

Il settore energetico è la principale fonte di emissioni in Italia con una quota superiore all'80%, comprese le emissioni fuggitive, per molti inquinanti (SO_X 92%; NO_X 91%; CO 92%; PM2.5 84%; BC 89%; PAH 86%, HCB 91%). Il settore dei processi industriali è un'importante fonte di emissioni specificamente legate alla produzione siderurgica, almeno per particolato, metalli pesanti e POP, mentre significative emissioni di SO_X derivano dalla produzione di nerofumo e acido solforico; il settore dell'uso di solventi e altri prodotti è invece caratterizzato da emissioni di COVNM. Il settore agricolo è la principale fonte di emissioni di NH_3 in Italia con una quota del 91% sul totale nazionale. Infine, il settore dei rifiuti, in particolare l'incenerimento dei rifiuti, è una fonte rilevante di BC (10%), Cd (10%), HCB (9%) e diossine (17%).

I dati sulle emissioni dell'inventario italiano delle emissioni e altri documenti correlati sono disponibili al pubblico su https://emissioni.sina.isprambiente.it/inventario-nazionale/ .

1 INTRODUCTION

1.1 Background information on the convention on long-range transboundary air pollution

The 1979 Geneva Convention on Long-range Transboundary Air Pollution, contributing to the development of international environmental law, is one of the fundamental international means for the protection of human health and the environment through intergovernmental cooperation. The fact that air pollutants could travel several thousands of kilometers before deposition and damage occurred outlined the need for international cooperation. In November 1979, in Geneva, 34 Governments and the European Community (EC) signed the Convention. The Convention on Long-range Transboundary Air Pollution was ratified by Italy in the year 1982 and entered into force in 1983. It has been extended by the following eight specific protocols:

- The 1984 Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP); 42 Parties. Entered into force on 28th January 1988.

- The 1985 Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by at least 30 per cent; 23 Parties. Entered into force on 2nd September 1987.

- The 1988 Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes; 31 Parties. Entered into force on 14th February 1991.

- The 1991 Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes; 22 Parties. Entered into force on 29th September 1997.

- The 1994 Protocol on Further Reduction of Sulphur Emissions; 27 Parties. Entered into force on 5th August 1998.

- The 1998 Protocol on Heavy Metals; 28 Parties. Entered into force on 29 December 2003.

- The 1998 Protocol on Persistent Organic Pollutants (POPs); 28 Parties. Entered into force on 23rd October 2003.

- The 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone; 23 Parties. Entered into force on 17th May 2005. (Guidance documents to Protocol adopted by decision 1999/1).

- The 2001 Stockholm Convention on Persistent Organic Pollutants (POPs), 186 Parties. Entered into force on 17 May 2004.

The following table shows the dates of signature and ratification of Convention and Protocols for Italy.

Table 1.1 Dates of signature and ratification of the UNECE Convention and Protocols

	SIGNATURE	RATIFICATION
1979 Convention	14/11/1979	15/07/1982
1984 EMEP Protocol	28/09/1984	12/01/1989
1985 Sulphur Protocol	09/07/1985	05/02/1990
1988 NO_x Protocol	01/11/1988	19/05/1992
1991 VOC Protocol	19/11/1991	30/06/1995
1994 Sulphur Protocol	14/06/1994	14/09/1998
1998 Heavy Metals Protocol	24/06/1998	
1998 POPs Protocol	24/06/1998	20/06/2006
1999 Multi-effect Protocol (reviewed in 2012)	01/12/1999	
2001 Stockholm Convention on POPs	23/01/2001	12/07/2022

The following classes of pollutants should be included in the emission inventory:

Main Pollutants

- Sulphur oxides (SO_X), in mass of SO_2;
- Nitrous oxides (NO_X), in mass of NO_2;

- Non-methane volatile organic compounds (NMVOC);
- Ammonia (NH_3);
- Carbon monoxide (CO).

Particulate matter

- TSP, total suspended particulate;
- PM10, particulate matter less than 10 microns in diameter;
- PM2.5, particulate matter less than 2.5 microns in diameter;
- Black carbon.

Heavy Metals

- Priority Metals: Lead (Pb), Cadmium (Cd) and Mercury (Hg);
- Other metals: Arsenic (As), Chrome (Cr), Copper (Cu), Nickel (Ni), Selenium (Se) and Zinc (Zn).

Persistent organic pollutants (POPs)

- As specified in Annex II of the POPs Protocol, including Polychlorinated Biphenyls (PCBs);
- As specified in Annex III of the POPs Protocol: Dioxins (Diox), Polycyclic Aromatic Hydrocarbons (PAHs), Hexachlorobenzene (HCB).

1.2 National inventory

As a Party to the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution (CLRTAP), Italy must submit annually data on emissions of air pollutants in order to fulfil obligations, in compliance with the implementation of Protocols under the Convention. Parties are required to report on annual national emissions of SO_X, NO_X, NMVOC, CO and NH_3, and various heavy metals and POPs according to the Guidelines for Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution (UNECE, 2008). The same data are submitted also in the framework of the National Emission Ceiling Directive of the European Union (EU, 2016). Specifically, the submission consists of the national LRTAP emission inventory, communicated through compilation of the Nomenclature For Reporting (NFR), and the Informative Inventory Report (IIR).

The Italian informative inventory report contains information on the national inventory for the year 2023, including descriptions of methods, data sources, QA/QC activities carried out and a trend analysis. The inventory accounts for anthropogenic emissions of the following substances: sulphur oxides (SO_X), nitrogen oxides (NO_X), ammonia (NH_3), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), total suspended particulate (TSP), particulate matter, particles of size <10 µm, (PM10), particulate matter, particles of size < 2.5µm, (PM2.5), black carbon (BC), lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), selenium (Se), zinc (Zn), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAH), dioxins (Diox), hexachlorobenzene (HCB). Other pollutants are reported as not estimated; more in details polycyclic aromatic hydrocarbons have not been estimates for each compound for all the sectors and further investigation is planned for the reporting of these emissions.

Detailed information on emission figures of primary pollutants, particulate matter, heavy metals and persistent organic pollutants as well as estimation procedures are provided in order to improve the transparency, consistency, comparability, accuracy and completeness of the inventory provided.

The national inventory is updated annually in order to reflect revisions and improvements in the methodology and the availability of new information. Changes are applied retrospectively to earlier years, which accounts for any difference in previously published data. Total emissions by pollutant from 1990 to 2023 are reported in Table 1.2.

Table 1.2 Emission time series by pollutant

		1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
SO_x	Gg	1,784	1,322	756	411	222	127	85	79	87	72
NO_x	Gg	2,125	1,988	1,516	1,302	961	727	585	596	590	557
NMVOC	Gg	2,007	2,079	1,662	1,374	1,154	948	893	901	849	871
NH_3	Gg	529	515	517	482	427	407	400	388	348	382
CO	Gg	6,824	7,118	4,814	3,527	3,107	2,303	1,881	2,051	1,914	1,849
As	Mg	37	28	39	28	17	9	5	6	6	5
Cd	Mg	11	11	10	9	5	5	4	5	4	4
Cr	Mg	95	79	55	62	51	46	37	44	43	41
Cu	Mg	389	440	466	496	449	441	305	368	381	381
Hg	Mg	15	14	15	13	9	7	6	6	6	5
Ni	Mg	116	112	109	114	43	33	28	30	33	30
Pb	Mg	4,302	2,021	991	327	246	228	179	213	207	203
Se	Mg	8	8	9	9	8	8	6	7	7	6
Zn	Mg	971	962	925	999	895	837	720	861	790	784
TSP	Gg	499	499	440	440	483	343	304	314	299	295
PM10	Gg	346	342	298	280	300	230	199	213	201	198
PM2.5	Gg	236	234	202	182	206	165	139	151	143	139
BC	Gg	46	45	42	38	32	23	18	19	17	17
PAH	Mg	90	92	59	64	87	71	61	69	63	61
Dioxin	g ITeq	529	508	430	361	343	312	282	327	305	297
HCB	kg	142	110	33	27	16	16	11	13	12	12
PCB	kg	154	166	157	179	133	114	104	122	109	106

The NFR files and other related documents can be found on the website at the following address: https://emissioni.sina.isprambiente.it/inventario-nazionale/ .

1.3 Institutional arrangements

The Institute for Environmental Protection and Research (ISPRA) has the overall responsibility for the compilation of the national emission inventory and submissions to CLRTAP. The Institute is also responsible for the communication of pollutants under the NEC directive as well as, jointly with the Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), the development of emission scenarios, as established by the Legislative Decree n. 171 of 21st May 2004. Every four years, from 2017 with reference to 2015 emissions, ISPRA shall provide the disaggregation of the national inventory at provincial level as instituted by the Legislative Decree n. 81 of 30 May 2018. Moreover, ISPRA is the single entity in charge of the development and compilation of the national greenhouse gas emission inventory as indicated by the Legislative Decree n. 51 of 7th March 2008. The Ministry of Environment and energy security (MASE) is responsible for the endorsement and for the communication of the inventory to the Secretariat of the different conventions. The Italian National System currently in place is fully described in the document 'National Greenhouse Gas Inventory System in Italy' (ISPRA, 2018).

A specific unit of the Institute is responsible for the compilation of the Italian Atmospheric Emission Inventory and the Italian Greenhouse Gas Inventory in the framework of both the Convention on Climate Change and the Convention on Long Range Transboundary Air Pollution. The whole inventory is compiled by the Institute; scientific and technical institutions and consultants may help in improving information both on activity data and emission factors of specific activities. All the measures to guarantee and improve the transparency, consistency, comparability, accuracy and completeness of the inventory are undertaken.

ISPRA bears the responsibility for the general administration of the inventory, co-ordinates participation in review processes, publishes and archives the inventory results. Specifically, ISPRA is responsible for all aspects of national inventory preparation, reporting and quality management. Activities include the collection and processing of data from different data sources, the selection of appropriate emissions factors and estimation methods consistent with the EMEP/EEA guidebook, the IPCC 1996 Revised Guidelines, the IPCC Good Practice Guidance and Uncertainty management and the IPCC Good Practice Guidance for land use, land-use change and forestry, and the IPCC 2006 Guidelines, the compilation of the inventory following the QA/QC procedures, the preparation of the Informative Inventory Report and the reporting through the Nomenclature Reporting Format, the response to review checks, the updating and data storage.

Different institutions are responsible for statistical basic data and data publication, which are primary to ISPRA for carrying out estimates. These institutions are part of the National Statistical System (Sistan), which provides national official statistics, and therefore are asked periodically to update statistics; moreover, the National Statistical System ensures the homogeneity of the methods used for official statistics data through a coordination plan, involving the entire public administration at central, regional and local levels.

The main Sistan products, which are primarily necessary for the inventory compilation, are:

- National Energy Balance (annual), Petrochemical Bulletin (quarterly publication), by MASE (Ministry of Environment);
- Transport Statistics Yearbooks, by MIMS (Ministry of Transportation);
- Annual Statistics on Electrical Energy in Italy, by TERNA (National Independent System Operator);
- Annual Report on Waste, by ISPRA;
- National Statistical Yearbooks, Monthly Statistical Bulletins, by ISTAT (National Institute of Statistics);
- Annual Report on the Energy and Environment, by ENEA (Agency for New Technologies, Energy and the Environment);
- National Forestry Inventory, by MASAF (Ministry of Agriculture, Food and Forest Policies).

The national emission inventory itself is a Sistan product. Other information and data sources are used to carry out emission estimates, which are generally referred to in Table 1.3 in the following section 1.5.

1.4 Inventory preparation process

ISPRA has established fruitful cooperation with several governmental and research institutions as well as industrial associations, which helps improve information about some leading categories of the inventory. Specifically, these activities aim at the improvement of provision and collection of basic data and emission factors, through plant-specific data, and exchange of information on scientific research and new sources. Moreover, when in depth investigation is needed and estimates are affected by a high uncertainty, sectoral studies are committed to ad hoc research teams or consultants. ISPRA also coordinates with different national and regional authorities and private institutions for the cross-checking of parameters and estimates, as well as with ad hoc expert panels, in order to improve the completeness and transparency of the inventory.

The main basic data needed for the preparation of the national emission inventory are energy statistics, published by the Ministry of Environment (MASE) in the National Energy Balance (BEN), statistics on industrial and agricultural production, published by the National Institute of Statistics (ISTAT), statistics on transportation, provided by the Ministry of Transportation (MIT), and data supplied directly by the relevant professional associations. Emission factors and methodologies used in the estimation process are consistent with the EMEP/EEA Guidebook, the IPCC Guidelines and Good Practice Guidance as well as supported by national experiences and circumstances.

For the industrial sector, emission data collected through the national Pollutant Release and Transfer Register (Italian PRTR), the Large Combustion Plant (LCP) Directive and in the framework of the European Emissions Trading Scheme have yielded considerable developments in the inventory of the relevant sectors. In fact, these data, even if not always directly used, are considered as a verification of emission estimates and improve national emissions factors as well as activity data figures. In addition, final estimates are checked and verified also in view of annual environmental reports by industries. For large industrial point sources, emissions are registered individually, when communicated, based upon detailed information such as fuel consumption. Other small plants communicate their emissions which are also considered individually. Emission estimates are drawn up for each sector. Final data are communicated to the UNECE Secretariat filling in the NFR files.

The process of the inventory preparation is carried out annually. In addition to a new year, the entire time series is checked and revised during the annual compilation of the inventory. Recalculations are elaborated on account of changes in the methodologies used to carry out emission estimates, changes due to different allocation of emissions as compared to previous submissions and changes due to error corrections. The inventory may also be expanded by including categories not previously estimated if enough information on activity data and suitable emission factors have been identified and collected. Information on the major recalculations is provided in the sectoral chapter of the report.

All the reference material, estimates and calculation sheets, as well as the documentation on scientific papers and the basic data needed for the inventory compilation, are stored and archived at the Institute. After each reporting cycle, all database files, spreadsheets and electronic documents are archived as 'read-only-files' so that the documentation and estimates could be traced back during the new year inventory compilation or a review process.

Technical reports and emission figures are publicly accessible on the web at the address https://emissioni.sina.isprambiente.it/inventario-nazionale/.

1.5 Methods and data sources

An outline of methodologies and data sources used in the preparation of the emission inventory for each sector is provided in the following. In Table 1.3 a summary of the activity data and sources used in the inventory compilation is reported.

Table 1.3 Main activity data and sources for the Italian Emission Inventory

	Activity data	Source
1 Energy		
1A1 Energy Industries	Fuel use	Energy Balance - MASE Major national electricity producers European Emissions Trading Scheme
1A2 Manufacturing Industries	Fuel use	Energy Balance - MASE Major National Industry Corporation European Emissions Trading Scheme
1A3 Transport	Fuel use Number of vehicles Aircraft landing and take-off	Energy Balance - MASE Statistical Yearbooks - National Statistical System Statistical Yearbooks - Ministry of Transportation Statistical Yearbooks -Italian Civil Aviation Authority (ENAC) Maritime and Airport local authorities
1A4 Residential-public-commercial sector	Fuel use	Energy Balance - MASE
1B Fugitive Emissions from Fuel	Amount of fuel treated	Energy Balance - MASE Statistical Yearbooks - Ministry of Transportation Major National Industry Corporation
2 Industrial Processes	Production data	European Emissions Trading Scheme European Pollutant Release and Transfer Register Sectoral Industrial Associations National Statistical Yearbooks- National Institute of Statistics International Statistical Yearbooks-UN
2D Solvent and Other Product Use	Amount of solvent use	National Environmental Publications - Sectoral Industrial Associations International Statistical Yearbooks-UN
3 Agriculture	Agricultural surfaces Production data Number of animals Fertilizer consumption	Agriculture Statistical Yearbooks - National Institute of Statistics Sectoral Agriculture Associations
4 Land Use, Land Use Change	Forest and soil surfaces Amount of biomass	Statistical Yearbooks - National Institute of Statistics

	Activity data	Source
	Biomass burnt Biomass growth	National and Regional Forestry Inventory - Carabinieri Universities and Research Institutes
5 Waste	Amount of waste	National Waste Cadastre - Institute for Environmental Protection and research

Methodologies are consistent with the EMEP/EEA Emission Inventory Guidebook, Revised 1996 and 2006 IPCC Guidelines, and IPCC Good Practice Guidance (EMEP/CORINAIR, 2007; EMEP/EEA, 2009; EMEP/EEA, 2013; EMEP/EEA, 2016; EMEP/EEA, 2019; EMEP/EEA, 2023; IPCC, 1997; IPCC, 2000; IPCC, 2006); national emission factors are used as well as default emission factors from international guidebooks, when national data are not available. The development of national methodologies is supported by background documents. The most complete document describing national methodologies used in the emission inventory compilation is the National Inventory Document, submitted in the framework of the UN Convention on Climate Change and the Kyoto Protocol (ISPRA, 2025 [a]). Activity data used in emission calculations and their sources are briefly described here below.

In general, for the energy sector, basic statistics for estimating emissions are fuel consumption published in the National Energy Balance by the Ministry of Environment. Additional information for electricity production is provided by the major national electricity producers and by the major national industry corporation. On the other hand, basic information for road transport, maritime and aviation, such as the number of vehicles, harbour statistics and aircraft landing and take-off cycles are provided in statistical yearbooks published both by the National Institute of Statistics and the Ministry of Transportation such as international organizations (i.e. Eurocontrol). Other data are communicated by different category associations. Data from the Italian Emissions Trading Scheme database (ETS) are incorporated into the national inventory whenever the sectoral coverage is complete; in fact, these figures do not always entirely cover the energy categories whereas national statistics, such as the national energy balance and the energy production and consumption statistics, provide the complete basic data needed for the Italian emission inventory. However, the analysis of data from ETS is used to develop country-specific emission factors and check activity data levels. In this context, ISPRA is also responsible for developing, operating and maintaining the national registry under Directive 2003/87/CE as instituted by the Legislative Decree 51 of March 7th 2008; the Institute performs this tasks under the supervision of the national Competent Authority for the implementation of directive 2003/87/CE, amended by Directive 2009/29/EC, jointly established by the Ministry for Environment, Land and Sea and the Ministry for Economic Development.

For the industrial sector, the annual production data are provided by national and international statistical yearbooks. Emission data collected through the national Pollutant Release and Transfer Register (Italian PRTR) are also used in the development of emission estimates or considered as a verification of emission estimates for some specific categories. Italian PRTR data are reported by operators to national and local competent authorities for quality assessment and validation. ISPRA collects facilities' reports and supports the validation activities at national and at local level. ISPRA communicates to the Ministry of Environment and to the European Commission within 30th April of the current year for data referring to the previous year. These data are used for the compilation of the inventory whenever they are complete in terms of sectoral information; in fact, industries communicate figures only if they exceed specific releases thresholds; furthermore, basic data such as fuel consumption are not required, and production data are not split by product but reported as an overall value. Anyway, the national PRTR is a good basis for data checks and a way to facilitate contacts with industries which supply, under request, additional information as necessary for carrying out sectoral emission estimates. In addition, final emissions are checked and verified also considering figures reported by industries in their annual environmental reports.

Both for energy and industrial processes, emissions of large industrial point sources are registered individually; communication also takes place in the framework of the European Directive on Large Combustion Plants, based upon detailed information such as fuel consumption. Other small plants communicate their emissions which are also considered individually.

For the other sectors, i.e. for solvents, the amount of solvent use is provided by environmental publications of sector industries and specific associations as well as international statistics. For agriculture, annual production data and number of animals are provided by the National Institute of Statistics and other sectoral associations. For waste, the main activity data are provided by the Institute for Environmental Protection and Research. When basic data are not available proxy variables are considered; unpublished data are used only if supported by personal communication and confidentiality of data is respected. All the material and documents used for the inventory emission estimates are stored at the Institute for Environmental Protection and Research. The inventory is composed of spreadsheets to calculate emission estimates; activity data and emission factors as well as methodologies are referenced to their data sources. A 'reference' database has also been developed to increase the transparency of the inventory; at the moment, it is complete as far as references to greenhouse gas emissions are concerned.

1.6 Key categories

A key category analysis of the Italian inventory is carried out according to the Approach 1 method described in the EMEP/EEA Guidebook (EMEP/EEA, 2023). According to these guidelines, a key category is defined as an emission category that has a significant influence on a country's inventory in terms of the absolute level in emissions. Key categories are those which, when summed together in descending order of magnitude, add up to over 80% of the total emissions. National emissions have been disaggregated into the categories reported in the NFR; details vary according to different pollutants in order to reflect specific national circumstances. Results are reported in the following tables for the year 1990 (Table 1.4) and 2023 (Table 1.5) by pollutant. The trend analysis has also been applied considering 1990 and 2023. The results are reported in Table 1.6.

Table 1.4 Key categories for the Italian Emission Inventory in 1990

	Key categories in 1990													Total (%)
SO_x	1A1a (43.1%)	1A1b (10.8%)	1A2c (7.2%)	1A3d ii (4.4%)	1A4b i (4.1%)	1B2a iv (3.8%)	1A2gviii (3.7%)	1A2f (3.6%)						80.6
NO_x	1A3b i (27.8%)	1A1a (19.2%)	1A3b iii (16.0%)	1A2f (5.7%)	1A4c ii (4.8%)	1A3d ii (4.5%)	1A3b ii (2.9%)							80.9
NH_3	3Da1 (21.3%)	3Da2a (18.0%)	3B1a (17.6%)	3B1b (16.7%)	3B3 (6.9%)									80.5
NMVOC	1A3b i (21.4%)	2D3d (13.5%)	1A3b iv (8.7%)	2D3a (7.6%)	1A3b v (5.9%)	1A4b i (4.9%)	2D3g (3.8%)	1A4c ii (3.4%)	2D3i (3.4%)	1B2a v (3.0%)	3B1a (2.4%)	3B1b (2.4%)		80. 7
CO	1A3b i (60.4%)	1A4b i (11.5%)	1A3b iv (7.2%)	1A4c ii (4.1%)										83.3
PM10	1A4b i (19.5%)	1A1a (10.9%)	2A5b (10.9%)	1A3b i (5.6%)	1A4c ii (4.6%)	1A3b iii (3.9%)	3Dc (3.7%)	1A3b ii (3.0%)	1A2f (2.9%)	2A5a (2.8%)	1A3d ii (2.7%)	1A3b vi (2.6%)	3B4g ii (2.4%)	81.3
	2C1 (2.1%)	2A1 (2.0%)	1A2a (1.8%)											
PM2.5	1A4b i (28.2%)	1A1a (10.7%)	1A3b i (8.2%)	1A4c ii (6.8%)	1A3b iii (5.7%)	1A3b ii (4.4%)	1A3d ii (3.9%)	1A2f (3.3%)	2C1 (2.5%)	1A2a (2.1%)	1A3bvi (2.0%)	1A1b (1.7%)	2A1 (1.6%)	81.0
BC	1A4c ii (19.4%)	1A3b i (19.0%)	1A3b iii (14.6%)	1A4b i (11.2%)	1A3b ii (11.1%)	1A2g vii (5.0%)								80.4
Pb	1A3b i (77.4%)	1A3b iv (5.2%)												82.6
Cd	1A2b (26.0%)	1A2a (19.1%)	2C1 (11.9%)	1A4b i (9.1%)	1A2f (5.2%)	2G (4.5%)	1A4a i (3.4%)	2B10a (3.1%)						82.3
Hg	1B2d (22.2%)	2B10a (18.4%)	2C1 (15.0%)	1A2b (10.6%)	1A2f (8.3%)	1A1a (6.5%)								81.1
PAH	2C1 (53.8%)	1A4b i (35.4%)												89.2
Dioxin	1A4a i (19.6%)	1A2a (15.4%)	1A4b i (13.2%)	2C1 (12.7%)	5C1a (8.1%)	5E (5.9%)	5C1b i (5.9%)							80.7
HCB	3Df (83.4%)													83.4
PCB	2C1 (59.4%)	1A2a (25.6%)												85.1

1 Energy	2 IPPU - Solvent and product use	5 Waste
2 IPPU - Industry	3 Agriculture	6 Other

Table 1.5 Key categories for the Italian Emission Inventory in 2023

	Key categories in 2023													Total (%)
SO_x	1A2f (27.5%)	1B2a iv (16.2%)	1A3d ii (11.2%)	1A4b i (6.7%)	1A1b (6.3%)	1A4ai (5.9%)	1A1a (5.8%)	2B10a (5.6%)						85.2
NO_x	1A3b i (19.3%)	1A3d ii (14.9%)	1A3b iii (14.0%)	1A3b ii (6.4%)	1A4b i (6.1%)	1A2f (5.1%)	1A4a i (4.9%)	1A4c ii (3.8%)	1A1a (3.7%)	3Da1 (3.5%)				81.8
NH_3	3Da1 (20.9%)	3B1a (14.0%)	3Da2a (13.8%)	3B1b (13.7%)	3B3 (10.2%)	6A (3.1%)	3B4g ii (3.1%)	3Da3 (3.1%)						81.9
NMVOC	2D3a (17.7%)	1A4bi (15.5%)	2D3d (14.1%)	1A3b v (5.8%)	2D3g (5.4%)	3B1a (4.5%)	3B1b (4.3%)	2D3i (3.8%)	1A4a i (3.2%)	2H2 (3.1%)	1A3b iv (2.8%)			80.1
CO	1A4b i (63.3%)	1A3b i (8.8%)	5C2 (4.4%)	1A3b iv (4.3%)										80.8
PM10	1A4b i (44.9%)	2A5b (10.8%)	3Dc (5.3%)	1A3b vi (5.2%)	1A3d ii (3.3%)	2A5a (2.9%)	1A2f (2.4%)	1A3bvii (2.4%)	2D3i (2.1%)	5E (2.1%)				81.3
PM2.5	1A4b i (63.0%)	1A3d ii (4.6%)	1A3b vi (3.9%)	5E (3.0%)	1A2f (3.0)	2C1 (2.2%)	2D3i (2.0%)							81.7
BC	1A4b i (46.9%)	1A3d ii (9.6%)	1A3b i (8.4%)	1A3bvi (7.5%)	5C2 (6.2%)	1A3b iii (5.3%)								83.9
Pb	2C1 (30.8%)	1A2f (29.7%)	1A3b vi (18.4%)	2G (6.1%)										84.9
Cd	2C1 (21.9%)	1A2f (13.4%)	1A2a (10.1%)	5C2 (9.7%)	2G (8.9%)	1A4b i (8.6%)	1A3b i (6.2%)	1A3bvi (4.0%)						82.8
Hg	2C1 (51.1%)	1A2f (10.7%)	1A2a (7.6%)	1A1a (6.3%)	1A4ai (4.0%)	1A4b i (3.9%)								83.5
PAH	1A4b i (78.6%)	2C1 (11.4%)												90.0
Dioxin	1A4b i (31.4%)	2C1 (27.1%)	1A2b (17.8%)	5E (14.3%)										90.5
HCB	1A2b (50.6%)	1A4a i (14.0%)	1A4b i (12.3%)	5C1biii (8.2%)										85.1
PCB	2C1 (71.7%)	1A4b i (14.0%)												85.7

1 Energy	2 IPPU - Solvent and product use	5 Waste
2 IPPU - Industry	3 Agriculture	6 Other

Table 1.6 Key categories for the Italian Emission Inventory in trend 1990-2023

	Key categories in trend													Total (%)
SOx	1A1a (29.7%)	1A2f (19.0%)	1B2a iv (9.9%)	1A2c (5.6%)	1A3d ii (5.4%)	1A4a i (4.6%)	1A1b (3.6%)	1B2c (2.8%)						80.5
NOx	1A1a (22.8%)	1A3dii (15.2%)	1A3b i (12.4%)	1A4a i (6.5%)	1A4b i (5.4%)	1A3b ii (5.2%)	1A2C (3.4%)	1A4c i (3.2%)	3Da1 (3.1%)	1A3b iii (2.9%)	3Da2a (2.9%)			82.9
NH3	3Da2a (14.7%)	3B1a (12.7%)	3B3 (11.5%)	3B1b (10.7%)	3Da2c (7.1%)	1B2d (5.2%)	3B4a (5.2%)	6A (5.0%)	1A3bi (4.1%)	3Da3 (4.1%)				80.3
NMVOC	1A3b i (26.5%)	1A4b i (14.0%)	2D3a (13.4%)	1A3b iv (7.9%)	1A4a i (4.0%)	1A4c ii (3.9%)	3B1a (2.8%)	3B1b (2.4%)	2D3g (2.1%)	2H2 (2.0%)	1B2av (1.7%)			80.9
CO	1A4b i (42.3%)	1A3b i (42.2%)												84.5
PM10	1A4b i (32.8%)	1A1a (13.9%)	1A3bi (5.9%)	1A4cii (5.8%)	1A3biii (4.2%)	1A3b ii (3.5%)	1A3b vi (3.3%)	2A5a (2.5%)	1A2a (2.3%)	3Dc (2.1%)	1A1b (2.0%)	1A2c (1.8%)	5E (1.6%)	81.5
PM2.5	1A4b i (39.2%)	1A1a (11.8%)	1A3b i (7.5%)	1A4c ii (7.4%)	1A3b iii (5.4%)	1A3b ii (4.5%)	1A2a (2.3%)	1A3b vi (2.1%)						80.3
BC	1A4b i (30.3%)	1A4c ii (15.8%)	1A3b i (9.1%)	1A3b iii (7.9%)	1A3b ii (7.4%)	1A3d ii (5.7%)	1A3b vi (4.5%)							80.7
Pb	1A3b i (42.2%)	2C1 (16.0%)	1A2f (15.2%)	1A3b vi (9.6%)										83.0
Cd	1A2b (27.6%)	2C1 (12.3%)	1A2a (11.1%)	1A2f (10.1%)	5C2 (8.6%)	2G (5.5%)	1A3b i (5.3%)							80.4
Hg	2C1 (35.9%)	1B2d (18.3%)	2B10a (18.3%)	1A2b (10.2%)										82.7
PAH	1A4b i (45.1%)	2C1 (44.2%)												89.3
Dioxin	1A4a i (16.5%)	1A4b i (16.1%)	1A2a (13.6%)	2C1 (12.7%)	1A2b (11.3%)	5E (7.4%)	5C1a (7.1%)							84.7
HCB	3Df (45.1%)	1A2b (26.2%)	1A4a i (7.1%)	1A4b i (6.4%)										84.9
PCB	1A2a (43.7%)	2C1 (25.5%)	1A4b i (16.7%)											85.9

1 Energy	2 IPPU - Solvent and product use	5 Waste
2 IPPU - Industry	3 Agriculture	6 Other

1.7 QA/QC and verification methods

ISPRA has elaborated an inventory QA/QC procedures manual which describes specific QC procedures to be implemented during the inventory development process, facilitates the overall QA procedures to be conducted, as far as possible, on the entire inventory and establishes quality objectives (ISPRA, 2014). Specific QA/QC procedures and different verification activities implemented thoroughly in the current inventory compilation are figured out in the annual QA/QC plans (ISPRA, 2025 [b]). Quality control checks and quality assurance procedures together with some verification activities are applied both to the national inventory as a whole and at a sectoral level. Future planned improvements are prepared for each sector by the relevant inventory compiler; each expert identifies areas for sectoral improvement based on his own knowledge and in response to different inventory review processes.

In addition to routine general checks, source specific quality control procedures are applied on a case by case basis, focusing on key categories and on categories where significant methodological and data revision have taken place or new sources. Checklists are compiled annually by the inventory experts and collected by the QA/QC coordinator. These lists are also registered in the 'reference' database. General QC procedures also include data and documentation gathering. Specifically, the inventory analyst for a source category maintains a complete and separate project archive for that source category; the archive includes all the materials needed to develop the inventory for that year and is kept in a transparent manner. Quality assurance procedures regard different verification activities of the inventory. Feedback for the Italian inventory derive from communication of data to different institutions and/or at local level. Emission figures are also subjected to a process of re-examination once the inventory, the inventory related publications and the national inventory reports are posted on website, specifically https://emissioni.sina.isprambiente.it/inventario-nazionale/ and www.isprambiente.gov.it .

The preparation of environmental reports where data are needed at different aggregation levels or refer to different contexts, such as environmental and economic accounts, is also a check for emission trends. At national level, for instance, emission time series are reported in the Environmental Data Yearbooks published by the Institute, in the Reports on the State of the Environment by the Ministry of Environment and, moreover, figures are communicated to the National Institute of Statistics to be published in the relevant Environmental Statistics Yearbooks as well as used in the framework of the EUROSTAT NAMEA Project. Technical reviews of emission data submitted under the CLRTAP convention are undertaken periodically for each Party. Specifically, an in-depth review of the Italian inventory was carried out in 2010 and 2013 (UNECE, 2010; UNECE, 2013).

Moreover, under the European National Emission Ceiling Directive (NECD), an in-depth review has been conducted in the years 2017 to 2024 (EEA, 2017 [a]; EEA 2018; EEA 2019; EEA 2020; EEA 2021; EEA 2022; EEA, 2023; EEA, 2024). The main resulting findings and how the recommendations were addressed are reported in the following table.

Recommendations from TERT, considering revised estimates (RE) and technical corrections (TC)

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
IT-1A3bii-2024-0001	Yes	1A3bii Road transport: Light duty vehicles, NO_X, 2021	For category 1A3bii Road Transport: Light Duty Vehicles, NOX, 2021, the TERT notes that significant recalculations have been applied (>10% change) and there is a lack of transparency in the IIR, specifically in section 3.5.6 Recalculation (pg. 101). In response to a question raised during the review, Italy explained that the time series of road transport emissions has been revised based on the upgrade of COPERT model version, from version 5.6.1 to 5.7.3, in the 2024 submission. Among the various updates, a rebalancing of mileage between light duty vehicles and heavy-duty vehicles has occurred due to availability of	NO	Implemented, more info in the IIR

			revised road freight transport data. This update has entailed a reduction in light duty vehicles and the recalculation in NOX emissions. **The TERT recommends that Italy include detailed description of the recalculations and the implications for light duty vehicles in the next IIR submission to improve transparency.**		
IT-1A3di(i)-2023-0003	No	1A3di(i) International maritime navigation - Memo Item, $PM_{2.5}$, SO_2, 2021	For category 1A3di(i) International maritime navigation - Memo, PM2.5, SO2, 2021 and 2022, the TERT notes that there is a lack of transparency regarding the changes in sulphur content in fuels over time to estimate emissions from maritime activities in the 2024 IIR Guidebook, specifically in 3.7.2 Methodological issues (pg 104). This was raised during the 2023 NECD inventory review. In response to a question raised during the review, Italy explained that fuel oil represents 98% of the total international fuel consumption along the time series, and that this information has been added to the IIR. In addition, Italy points out that the sulphur content has been erroneously reported equal to 0.3% (IIR, pg 105, states 'For international navigation 0.3% of sulphur content in fuel oil has been assumed for the whole time series'). The correct sulphur content value is 3%. **The TERT reiterates the recommendation that Italy improve the description on how the sulphur content in fuels for maritime activities changes over time.**	NO	Implemented, more info in the IIR
IT-5B1-2022-0001	No	5B1 Biological treatment of waste - Composting, NH_3, 1990-2021	For category 5B1 Biological treatment of waste - Composting, NH3, all years, the TERT notes that the implied emission factor is 0.024 g/Mg of waste, which corresponds to the application of the Tier 2 methodology with an abatement efficiency of 90% applied to the total amount of waste composted. This was raised during the 2022 and 2023 NECD inventory reviews. The recommendation was to consider the penetration rate of abatement technologies and improve its methodological description. The TERT notes that the issue is below the threshold of significance for a technical correction. The TERT notes that the IIR Guidance (p. 199) states the issue has been included in the list of improvements and that Italy is looking for further information to apply the penetration of technologies back to 1990. **The TERT reiterates the recommendation that Italy provide further justification for its application of the 90% abated emission factor 0.024 g/Mg across its entire time series of NH3 emissions from 5B1 Compost production. If appropriate, Italy may need to recalculate the early time series using an unabated emission factor.**	NO	Implemented, more info in the IIR
CLRTAP 2024/1	Yes	2D3d NMVOC - transparency	The ERT (Expert Review Team) notes that recalculations were applied to Emission Factors (EFs) related to paint application in construction and buildings for the period between 2019 and 2021. It is also noted that detailed information on emission factors for paint used in construction and buildings throughout the years	NO	Implemented, more info in the IIR

			is provided in section 5.2.4 of the IIR, specifically under "Decorative coating (2D3d1)." Section 5.5 notes that a recalculation was made, however does not provide detail; **please can Italy clarify the specific parameters that contribute to the refinement and updating of emission factors (EFs) for the 2D3d1 sub-sector?.**		
CLRTAP 2024/2	Yes	2D NMVOC – transparency, accuracy	The ERT notes that reported NMVOC emissions from sub-categories 2D3a, 2D3b, 2D3c, 2D3d, 2D3e, 2D3f, and 2D3g, covering the years 1990 to 2022, make use of historic versions of the EMEP/EEA Guidebook, e.g. on p137 the 2016 EMEP/EEA Guidebook and EMEP/CORINAIR 2007 are mentioned and in some cases a reference to the 1992 EMEP/CORINAIR guidebook is made (p141). The methods for calculating NMVOC emissions from solvent and other product use (NFR sector 2D) have been updated in the 2019/2023 versions of the EMEP/EEA Guidebook. **Please can Italy provide details as to why historic versions of the Guidebook are used?**	NO	References to the historic versions of the Guidebook have been checked and revised where relevant
CLRTAP 2024/3	Yes	2D3a NMVOC – transparency, accuracy	For category 2D3a 'Domestic solvent use including fungicides', for pollutant NMVOC and years 2013, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, the ERT note that there is availability of new ESIG data which may provide evidence to update emission factors - the ERT note that on p138 it is stated that EFs have remained constant since the mid-1990s. **Have Italy carried out any comparisons between available ESIG data and submitted emissions data for sector 2D3a, or are there any plans to do so?**	NO	Verification with ESIG data has been carried out
CLRTAP 2024/4	Yes	2D3a NMVOC – completeness, transparency, accuracy	The ERT noted with reference to IIR page 137; 145; 146, tables 5.5; 5.6 and the data reported in the NFR tables that NMVOC emissions from 2D3a domestic solvent use including fungicides do not show a peak during the COVID-19 pandemic in the year 2020 [respectively: (2019 (90,94); 2020 (84,77); 2021 (96,21); 2022 (97,64)]. **Has the increased use of hand sanitizers been considered for the NMVOC emission estimates for 2D3a domestic solvent use?**	NO	Emission estimates for hand sanitizers have been revised
CLRTAP 2024/5	Yes	2D3i NMVOC - completeness	For category 2D3i "Other solvent use", the ERT notes that aircraft de-icing is not included when emission factors are available in the 2019 EMEP/EEA Guidebook (NMVOC EF = 53 Kg/ton deicing fluid used). **Is Italy considering the inclusion of aircraft de-icing in category 2D3i to improve the completeness of the solvent sector in the next submissions?**	NO	The inclusion of emissions from the aircraft de-icing needs further exploration because no data is currently available to estimate these emissions
CLRTAP 2024/6	Yes	General NMVOC - transparency	The ERT noted that Italy provides detailed tables on its spatial proxies for each source. However, Italy is not explaining the gridding methodology in general. The ERT, therefore, encourages Italy to include a paragraph/subchapter on the used gridding software with selected additional result maps for an illustration of the process. **This way Italy can significantly enhance the transparency of its gridding chapter in the IIR.**	NO	Some information has been included in the relevant chapter

Comparisons between national activity data and data from international databases are usually carried out in order to find out the main differences and an explanation to them. Emission intensity indicators among countries (e.g. emissions per capita, industrial emissions per unit of added value, road transport emissions per passenger car, emissions from power generation per kWh of electricity produced, emissions from dairy cows per tonne of milk produced) can also be useful to provide a preliminary check and verification of the order of magnitude of the emissions. Additional comparisons between emission estimates from industrial sectors and those published by the industry itself in the Environmental reports are carried out annually in order to assess the quality and the uncertainty of the estimates. The quality of the inventory has also improved through organization and participation in sector specific workshops. A specific procedure undertaken for improving the inventory regards the establishment of national expert panels (in particular, in road transport, land use change and forestry and energy sectors) which involve, on a voluntary basis, different institutions, local agencies and industrial associations cooperating for improving activity data and emission factors accuracy.

Furthermore, activities in the framework of the improvement of local inventories are carried out together with local authorities concentrating on the comparison between top down and bottom-up approaches and identifying the main critical issues. In 2021, ISPRA has finalized the provincial inventory at local scale for the years 1990, 1995, 2000, 2005, 2010, 2015 and 2019 applying a top-down approach. Methodologies and results were checked out by regional and local environmental agencies and authorities, and figures are available at ISPRA web address https://emissioni.sina.isprambiente.it/inventari-locali/ . Methodologies used for spatial disaggregation are described in related publications (ISPRA, 2009; ISPRA, 2022). This work is also relevant to carry out regional scenarios, for the main pollutants, within the Gains Italy project implemented by ENEA and supported by ISPRA and the regional authorities. In addition to these expert panels, ISPRA participates in technical working groups within the National Statistical System. These groups, named "Circoli di qualità" ("Quality Panels"), coordinated by the National Institute of Statistics, are constituted by both producers and users of statistical information with the aim of improving and monitoring statistical information in specific sectors such as transport, industry, agriculture, forest and fishing. These activities should improve the quality and details of basic data, as well as enable more organized and timely communication.

Other specific activities relating to improvements of the inventory and QA/QC practices regard the progress on management of information collected in the framework of different European obligations, Large Combustion Plant, E-PRTR and Emissions Trading, which is gathered together in an informative system thus highlighting the main discrepancies among data, detecting potential errors and improving the time series consistency. ISPRA collects these data from the industrial facilities and the inventory team manages the information and makes use of it in the preparation of the national inventory. The informative system is based on identification codes to trace back individual point sources in different databases and all the figures are considered in an overall approach and used in the compilation of the inventory. Proper archiving and reporting of the documentation related to the inventory compilation process is also part of the national QA/QC plan. All the material and documents used for the inventory preparation are stored at the Institute for Environmental Protection and Research. Information relating to the planning, preparation, and management of inventory activities is documented and archived. The archive is organized so that any skilled analyst could obtain relevant data sources and spreadsheets, reproduce the inventory and review all decisions about assumptions and methodologies undertaken. A master documentation catalogue is generated for each inventory year, and it is possible to track changes in data and methodologies over time. Specifically, the documentation includes:

- electronic copies of each of the draft and final inventory report, electronic copies of the draft and final NFR tables;
- electronic copies of all the final, linked source category spreadsheets for the inventory estimates (including all spreadsheets that feed the emission spreadsheets);
- results of the reviews and, in general, all documentation related to the corresponding inventory year submission.

After each reporting cycle, all database files, spreadsheets and electronic documents are archived as 'read-only' mode.

A 'reference' database is also compiled every year to increase the transparency of the inventory. This database consists of a number of records that references all documentation used during the inventory compilation, for each sector and submission year, the link to the electronically available documents and the place where they are stored as well as internal documentation on QA/QC procedures.

1.8 General uncertainty evaluation

Uncertainty assessment is an important part of compiling an emissions inventory and to assess how uncertainties evolve over time. It is impossible to eliminate uncertainty completely, leading to the conclusion that for every value reported in an inventory there will exist an associated uncertainty. Knowledge of this uncertainty is an integral part of the inventory compilation effort. Uncertainty in emission estimates is a function of the uncertainty of input data, i.e. activity or emission factors, used to compile the inventory. Hence, data collection and uncertainty evaluation are strongly linked and all data contributing to the estimation of emissions should have an associated uncertainty assessment.

Until the 2023 inventory submission, Italy had not systematically assessed the uncertainty of national estimates. Nevertheless, different studies on uncertainty have been carried out (Romano et al., 2004) and a quantitative assessment of the Italian GHG inventory is performed by the Tier 1 method defined in the 2006 IPCC Guidelines (IPCC, 2006) which provides a calculation based on the error propagation equations. Details on the results of the GHG inventory uncertainty figures can be found in the National Inventory Document 2025 (ISPRA, 2025 [a]). The EMEP/EEA Guidebook provides guidance on the quantification of uncertainties in emissions inventories and is aligned with the "2019 Refinement to the 2006 IPCC Guidelines for National GHG Inventories" guidance. Guidelines define two approaches to estimating uncertainties in national greenhouse gas inventories: Approach 1, based on the error propagation equations, and Approach 2, corresponding to the application of Monte Carlo analysis. The Italian inventory team plans to calculate quantitative estimates of the uncertainties using Approach 1 for most estimated pollutants in next years. As above reported, uncertainty in emission estimates is a function of the uncertainty of input data: activity and emission factors. The uncertainty associated with activity data has been borrowed from the National Inventory Document 2025 while values associated with EFs have been taken on the basis of ranges proposed by the 2019 EMEP/EEA Guidebook and the expert judgement of the sectoral experts. In 2023 Italy reported NO_X emissions uncertainty assessment, emission categories are disaggregated into a detailed level and uncertainties are therefore estimated for these categories. In addition, Italy has decided to achieve an in-depth analysis of the most important categories for which punctual data are available starting from the NO_X emissions of the thermoelectric power plants whose evaluation of the uncertainty is reported in 3.2.2.

As already mentioned, the Approach 1 has been applied to the Italian inventory to estimate uncertainties for the last submitted year and for the trend. In 2021, the results of Approach 1 for NOx suggest an uncertainty of 4.1% in the total emissions. The analysis also estimates an uncertainty of 0.9% in the trend. In the Table 1.7 a summary by sector is reported, detailed data have been reported in Appendix 2.

Table 1.7 Summary by sector of the uncertainty associated with the NOx inventory.

Sector	Emissions in base year Gg NOx	Emissions in year t Gg NOx	Contribution to total uncertainty by sector in year t %	Contribution to total trend uncertainty by sector %
Energy	2034.66	550.70	75.05	79.94
IPPU	25.05	5.18	0.02	0.04
Agriculture	61.66	52.69	24.74	19.83
Waste	2.68	2.12	0.19	0.19
Total	2124.05	610.69	100.00	100.00
Uncertainty in total inventory			**4.1**	**0.9**

It should be noted that different levels of uncertainty pertain to different pollutants. Estimates of the main pollutants are generally of high level, but PM emissions, especially those of small particle sizes, heavy metal and POP estimates are more uncertain. For this reason, even though not quantified in terms of uncertainty, improvements are planned especially for the specified pollutants. Nevertheless, since quantitative uncertainty assessments constitute a mean to either provide the inventory users with a quantitative assessment of the inventory quality or to direct the inventory preparation team to priority areas, the Italian Inventory team plans to evaluate uncertainties in the next years providing detailed results in the Appendix 2. In the previous submission, uncertainties for SOx have been evaluated for the last submitted year (2022) and in trend. While in the current submission uncertainties for CO have been evaluated for 2023.

In 2022, the results of Approach 1 for SOx suggest an uncertainty of 5.4% in the total emissions. The analysis also estimates an uncertainty of 0.3% in the trend. In the Table 1.8 a summary by sector is reported, detailed data has been reported in Appendix 2.

Table 1.8 Summary by sector of the uncertainty associated with the SOx inventory.

	Emissions in base year	Emissions in year t	Contribution to total uncertainty by sector in year t	Contribution to total trend uncertainty by sector
Sector	Gg SOx	Gg SOx	%	%
Energy	1714.39	81.19	98.61	99.78
IPPU	68.59	6.75	1.38	0.21
Agriculture	0.08	0.05	0.00	0.00
Waste	0.55	0.16	0.01	0.01
Total	1783.60	88.15	100.00	100.00
Uncertainty in total inventory			**5.4**	**0.3**

In 2023, the results of Approach 1 for CO suggest an uncertainty of 9.4% in total emissions. The analysis also estimates an uncertainty of 2.5% in the trend. In the Table 1.9 a summary by sector is reported, detailed data has been reported in Appendix 2.

Table 1.9 Summary by sector of the uncertainty associated with the CO inventory.

	Emissions in base year	Emissions in year t	Contribution to total uncertainty by sector in year t	Contribution to total trend uncertainty by sector
Sector	Gg CO	Gg CO	%	%
Energy	6523.35	1693.33	92.42	95.22
IPPU	220.04	60.95	0.06	0.01
Agriculture	18.49	14.24	0.23	0.10
Waste	61.69	80.65	7.29	4.67
Total	6823.58	1849.16	100.00	100.00
Uncertainty in total inventory			**9.4**	**2.5**

1.9 General assessment of completeness

The inventory covers all major sources, as well as all main pollutants, included in the UNECE reporting guidelines (UNECE, 2014). NFR sheets are complete as far as the details of basic information are available.

Allocation of emissions is not consistent with the guidelines only where there is not sufficient data available to split the information. For instance, emissions from category 1.A.5.a other stationary are reported and included under category 1.A.4.a i commercial and institutional emission estimates. Mobile commercial and institutional emission estimates (1.A.4.a ii) are included in 1.A.3 sector. PM and HMs emissions from 2.A.3 glass production are included in 1.A.2.f combustion category source as well as those from lead, zinc and copper production are included in 1.A.2.b category. HCB, PCB and Dioxin emissions from aluminium production are included in 1.A.2.b category as well as PM emissions from secondary aluminium production while HCB from iron and steel are included in 1.A.2.a category. NO_X, SO_X and NH_3 from 1.B.1.b, fugitive emissions from solid fuel transformation, are included in the 1.A.2.a category and HMs and POPs from 1.B.2.a iv are included in 1.A.1.b category. PM emissions from storage, handling and transport of mineral products (2.A.5.c) are included under the relevant emission categories.

There are a few emission sources not assessed yet: PAH, dioxin and PCB emissions from 1.A.3.b v gasoline evaporation, dioxin and PCB non-exhaust emissions from 1.A.3.b vi, automobile tyre and brake wear, HMs, PAH, dioxin and PCB non-exhaust emissions from 1.A.3.b vii, road abrasion, NH_3 emissions from 1.A.3.a domestic and international aviation LTO cycle, NH_3 from 1.A.3.e i, pipeline transportation, NO_X from 3.D.a iv, crop residues applied to soils, and 3.D.b, indirect emissions from managed soils. Emission factors for these categories, when available in the Guidebook (EMEP/EEA, 2023), need further assessment for the applicability to the national circumstances. PAH emissions are not detailed in the four indicator compounds for all the categories; the estimates for categories 1.A.1, 1.A.2 stationary, 1.A.3.a, 1.A.3.c, 1.A.3.d ii, 1.A.4.b ii, 1.A.4.c ii, 1.A.4.c iii, 1.A.5.b, 2.C.1, and 2.C.3 are not yet being made because for emission factors are not fully available by compound. Black carbon emissions from the categories reported in the NFR under 2.A.5 a, quarrying and mining of minerals other than coal, and 2.A.5.b, construction and demolition, are not estimated because no information on EF is still available. Emissions of PAH from asphalt blowing, 2.D.3g, are also under further investigation and reported as NE, although according to the relevant industrial association PAH emissions are negligible because all the asphalt blowing plants have abatement filter system of PM and afterburners of gas. Moreover, these plants should respect national environmental legislation not exceeding at the stack more than 0.1mg/Nm^3 for total PAH.

Further investigation will be carried out about these source categories and pollutants in order to calculate and improve figures.

2 ANALYSIS OF KEY TRENDS BY POLLUTANT

2.1 MAIN POLLUTANTS

In the following sections, Italian emission series of sulphur oxides, nitrogen oxides, non-methane volatile organic compounds, carbon monoxide and ammonia are presented.

2.1.1 Sulphur dioxide (SO_X)

The national atmospheric emissions of sulphur oxides have significantly decreased in recent years, as has occurred in almost all countries of the UNECE. Figure 2.1 and Table 2.1 show the emission trend from 1990 to 2023. Figure 2.1 also illustrates the share of SO_X emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.1 SO_X emissions trend, percentage share by sector and variation 1990-2023.

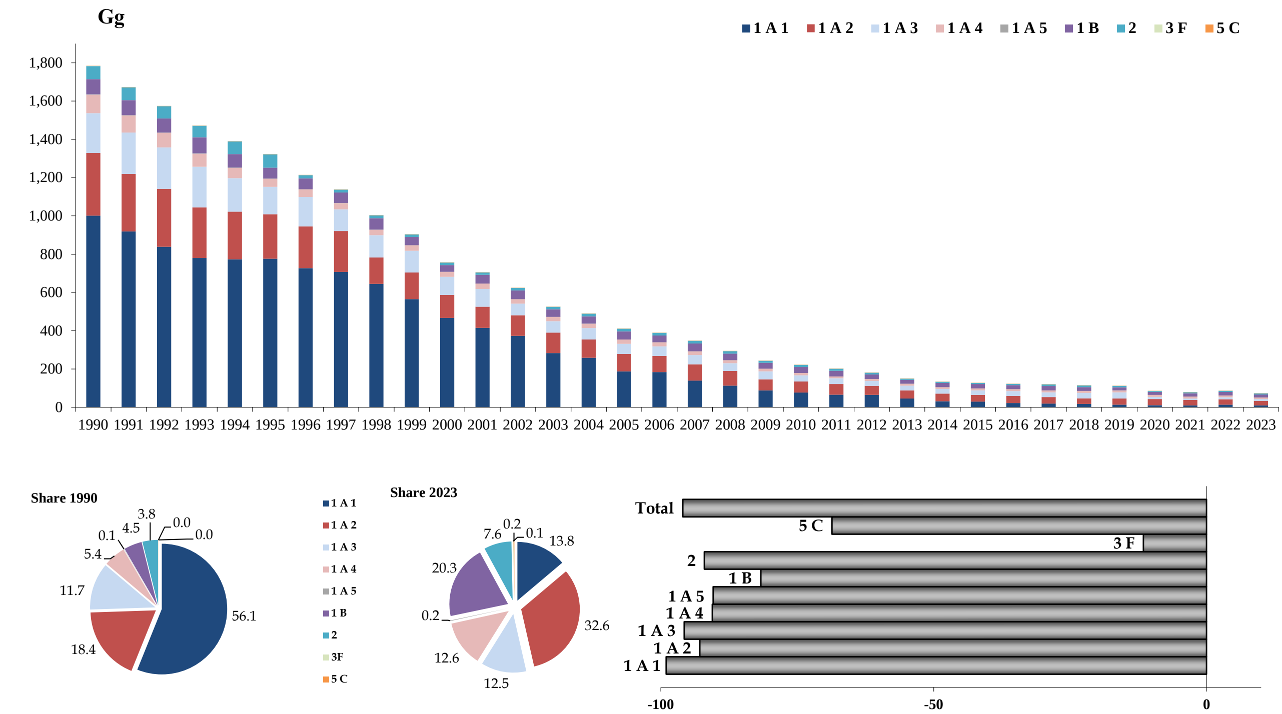


Table 2.1 SO_X emission trend from 1990 to 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	1,000.8	776.4	466.8	187.0	77.1	29.6	10.9	9.9	13.7	9.9
Non industrial combustion plants	82.3	32.5	25.0	22.7	12.1	10.3	9.8	10.0	9.2	9.1
Combustion - Industry	324.1	230.7	119.8	91.4	57.6	35.2	31.3	27.9	28.4	23.4
Production processes	136.0	115.5	38.8	46.4	35.9	24.3	16.7	19.1	20.9	17.0
Solvent and other product use	0.009	0.009	0.032	0.040	0.032	0.017	0.014	0.028	0.030	0.048

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Road transport	129.3	71.6	11.9	2.2	0.4	0.4	0.3	0.4	0.4	0.4
Other mobile sources and machinery	98.3	84.1	84.0	50.6	31.7	23.1	11.8	7.6	10.1	8.7
Waste treatment and disposal	12.9	11.6	10.0	10.7	7.0	4.5	4.0	4.1	3.9	3.2
Agriculture	0.1	0.1	0.1	0.1	0.1	0.1	0.07	0.07	0.07	0.07
Total	**1,783.6**	**1,322.4**	**756.5**	**411.1**	**221.8**	**127.5**	**84.9**	**79.2**	**86.6**	**71.9**

Figures show a general decline of SO_X emissions during the period, from 1,784 Gg in 1990 to 71.9 Gg in 2023. The national target of SO_X emissions, set by the National Emission Ceilings Directive at 475 Gg for 2010 (EC, 2001) was reached and continues to be respected after this year's revision of the time series. The targets established for 2020 in the framework of the UNECE/CLRTAP Convention and in the framework of 2030 of the revised National Emission Ceiling Directive (EU, 2016), equal for Italy respectively to 65% and 29% of 2005 emissions, has been already reached. The decreasing trend is determined mainly by the reduction in emissions from combustion in energy (-99%) and in industry (-93%), representing in 2023 about 14%, and 33% of the total, respectively. Emissions deriving from non-industrial combustion plants and road transport show a strong decrease too (-89% and -100%, respectively), but these emissions represent about 13% and 0.5% of the total in 2023. Production processes and other mobile sources and machinery also present a significant decreasing trend, showing an influence on the total of 24% and 12% and dropping by about -87% and -91%, respectively. Waste treatment and disposal account for 4% of the national total decreasing of about -75% with respect to 1990. SO_X emissions from agriculture and from solvent and other product use are also estimated but their contribution is irrelevant. An explanation of the sectoral decreasing trend is outlined more in detail in the following.

Combustion in energy and transformation industries

The trend of emissions of this sector shows a reduction in the early eighties mainly due to the use of natural gas in place of coal in energy production and to the implementation of the Directive EEC 75/716 (EC, 1975) which introduces more restrictive constraints in the sulphur content of liquid fuels. During the years 1985-1990, there was an increase in energy consumption that, not sufficiently hampered by additional measures, led to an increase in the emissions of the sector and consequently of total SO_X levels. However, in the nineties, there was an inverse trend due to the introduction of two regulatory instruments: the DPR 203/88 (Decree of President of the Republic of 24th May 1988), laying down rules concerning the authorization of plants, and the Ministerial Decree of 12th July 1990, which introduced plant emission limits. Also the European Directive 88/609/EEC (EC, 1988) concerning the limitation of specific pollutants originated from large combustion plants, transposed in Italy by the DM 8th May 1989 (Ministerial Decree of 8th May 1989) gave a contribution to the reduction of emissions in the sector.

Finally, in recent years, a further shift to natural gas in place of fuel oil and a further reduction in the use of coal fuels have contributed to a decrease in emissions.

Non industrial combustion plants

The declining of the emissions occurred mainly as a result of the increase in natural gas and LPG as alternative fuel to coal, diesel and fuel oil for heating; furthermore, several European Directives on the sulphur content in fuels were adopted. In accordance with national legislation, the sulphur content allowed in diesel fuel has decreased from 0.8% in 1980 to 0.2% in 1995 and 0.1% in 2008, while in fuel oil for heating from 3% in 1980 to 0.3% in 1998. Moreover, coal is not more allowed for residential and commercial heating.

Combustion in industry

Emissions from this sector show the same trend of reduction as the category previously analysed, as in the scope of the same rules.

Production processes

Emissions from refineries have been reduced as a result of compliance with the DM 12th July 1990 (Ministerial Decree of 12th July 1990), which introduces limit values. The reduction of emissions from chemical industry is due to the drop off of the sulphuric acid production and to the decrease of emissions in the production of carbon black.

Road transport

The reduction of emissions is mainly due to the introduction of European Directives regulating the sulphur content in liquid fuels.

Other mobile sources and machinery

As regards off roads, emissions mainly derive from maritime transport, which show a decrease due to the introduction of European Directives regulating the sulphur content in fuels.

2.1.2 Nitrogen oxides (NO_X)

The national atmospheric emissions of nitrogen oxides show a decreasing trend in the period 1990-2023, from 2,125 Gg to 557 Gg. Figure 2.2 and Table 2.2 show emission figures from 1990 to 2023. Figure 2.2 also illustrates the share of NO_X emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.2 NO_X emission trend, percentage share by sector and variation 1990-2023.

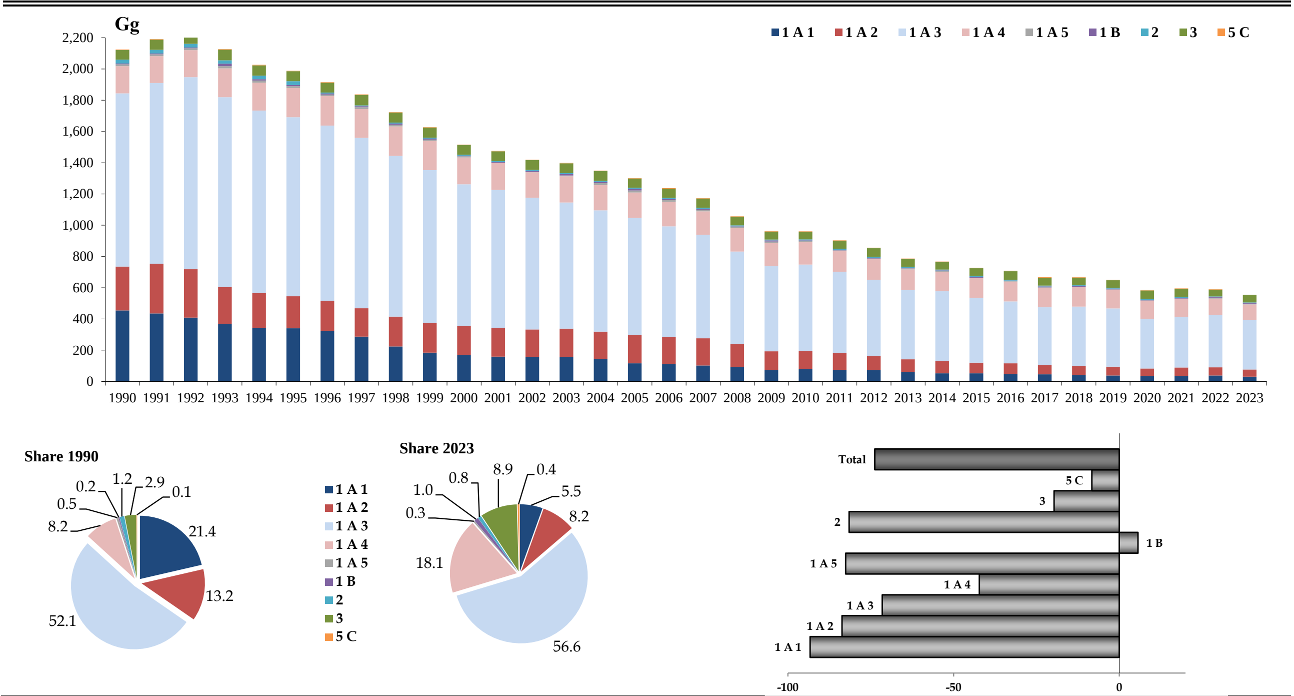


Table 2.2 NO_X emission trend from 1990 to 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	457.4	344.3	172.6	117.9	81.3	52.4	34.0	35.8	38.9	31.0

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Non industrial combustion plants	64.2	65.5	64.8	74.9	85.5	86.2	82.9	85.3	77.6	74.2
Combustion - Industry	250.6	182.4	154.0	155.5	100.2	60.3	45.9	49.9	48.6	43.0
Production processes	29.9	31.0	9.2	16.0	10.7	9.5	9.3	10.3	10.4	9.9
Solvent and other product use	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Road transport	996.1	1039.5	786.8	639.3	440.9	327.7	210.6	239.0	239.0	223.9
Other mobile sources and machinery	261.5	258.5	262.7	235.2	190.1	137.6	144.8	120.7	129.5	123.0
Waste treatment and disposal	3.0	2.9	2.6	3.2	3.0	2.9	2.7	2.8	2.6	2.7
Agriculture	61.8	64.2	63.5	59.8	49.3	50.3	54.5	52.1	43.6	49.7
Total	**2,124.7**	**1,988.4**	**1,516.3**	**1,302.0**	**961.1**	**727.1**	**584.9**	**596.0**	**590.3**	**557.4**

Total emissions show a reduction of about 74% from 1990 to 2023, with a marked decrease between 1995 and 2000, especially in the road transport and energy combustion sectors. The target value of emissions, fixed for 2010 by the National Emission Ceilings Directive (EC, 2001) at 990 Gg has been reached and continues to be respected. In 2015, in the framework of the UNECE/CLRTAP Convention, and in particular the Multieffects Protocol, a new target has been established for Italy equal to 60% of 2005 emissions in 2020 and it has been reached. Moreover, the revised National Emission Ceiling Directive (EU, 2016), established a target for Italy equal to 35% of 2005 emissions in 2030.

The main source of emissions is road transport (about 40% in 2023), which shows a reduction of 78% between 1990 and 2023; other mobile sources and machinery contributed to the total emissions for 22% in 2023 and have reduced by 53% from 1990. Combustion in energy and in industry shows a decrease of about -93% and -83%, respectively, having a share on the total of about 6% and 8% in 2023, respectively. Among the sectors concerned, the only one which highlights an increase in emissions is non-industrial combustion plants showing an increase of 16%, accounting for 13% of the total. Details on the sectoral emission trend and respective variation are outlined in the following sections, starting from the early eighties.

Combustion in energy and transformation industries

Emissions from this sector show an upward trend until 1988 due to an increase in energy consumption, which was not prevented by reduction measures. From 1988 onwards, emissions present a gradual reduction due, mainly, to the introduction of the two regulatory instruments already mentioned for sulphur dioxide: the DPR 203/88 (Decree of President of the Republic of 24th May 1988), laying down rules for the authorization of facilities and the Ministerial Decree of 12th July 1990, which introduces plant emission limits. The adoption of these regulations, as the Ministerial Decree of 8th May 1989 on large combustion plants, has led to a shift in energy consumption from oil with high sulphur content to oil with lower sulphur content and to natural gas.

In recent years, the conversion to the use of natural gas to replace fuel oil has intensified, thanks to incentives granted for the improvement of energy efficiency. Furthermore, a significant reduction in the use of coal fuels for energy production has been recorded in the last years. These measures, together with those of promoting renewable energy and energy saving, have led to a further reduction of emissions in the sector. In addition, in the last years, more stringent emission limits to the new plants have been established during the authorization process with the aim to prevent air quality issues at local level.

Non industrial combustion plants

The increase in emissions is explained by the growing trend of energy consumption during the period considered. This is because in the last twenty years all the new buildings have been equipped with heating systems and old buildings have been modernized.

A national survey on energy consumption of households, conducted by the National Institute of Statistics (ISTAT, 2014), has supplied the amount of biomass burned to heating. Estimated values of biomass burnt are about 80% higher than previous estimates reported in the National Energy Balance (MASE, several years) and derived from regional or incomplete surveys. From 2013 these new biomass figures are reported in the National Energy Balance. In 2015 the reconstruction backwards of the time series has been finalised, with the collaboration of ISTAT and GSE (Energy Services Manager), and official data have been communicated to Eurostat. Furthermore, the continuous improvement of appliances for biomass combustion has led to a significant reduction in emissions for different pollutants (PM, COVNM, PAH) but on the other hand an increase of NO_x EFs because of the optimization of combustion process.

Combustion in industry

Emissions from this sector show a decreasing trend, motivated by the same reasons as the energy industry, having undergone the same legislation.

Road transport

The decrease is the result of two opposing trends: an increase in emissions in the early years of the historical series, with a peak in 1992, due to the increase in the fleet and in the total mileage of both passengers and goods transported by road, and a subsequent reduction in emissions. This decrease is, once more, the result of two opposing trends: on one hand, the growth of both the fleet and the mileage, on the other hand the introduction of technologies to reduce vehicle emissions, as the catalytic converter, provided by European Directives, in particular the Directives 91/441/EC (EC, 1991), 94/12/EC (EC, 1994) and 98/69/EC (EC, 1998) and subsequent modifications and integrations.

To encourage the reduction of emissions, different policies have also been implemented, including incentives to renew the public and private fleet and for the purchase of electric vehicles, promotion for the integrated expansion of rail, maritime and urban transport system, and programmes of sustainable mobility. In 2020 pandemic and relevant lockdown measures affected 2020 emission levels especially for this sector.

Other mobile sources and machinery

From 1980 emissions have a slightly rising trend until 1998 and then decrease slightly until arriving in 2017 at lower levels. Emissions in the sector are characterized predominantly by maritime transport, by machinery used in agriculture and industry.

Regarding mobile machinery used in agriculture and industry, these sectors were not governed by any legislation until the Directive 97/68/EC (EC, 1997 [a]), which provides for a reduction in NO_X limits from 1st January 1999, and Directive 2004/26/EC (EC, 2004) which provide further reduction stages with substantial effects from 2011, with a following decreasing trend particularly in recent years.

2.1.3 Ammonia (NH_3)

The national atmospheric emissions of ammonia show a slight decline in the period 1990-2023, from 529 Gg to 382 Gg. Figure 2.3 and Table 2.3 report the emission figures from 1990 to 2023. Figure 2.3 also illustrates the share of NH_3 emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

According to the National Emission Ceilings Directive, the target value of emissions for 2010 amounts to 419 Gg which was achieved. The target established for 2020 in the framework of the UNECE/CLRTAP Convention and relevant protocol is equal for Italy to 95% of 2005 emissions and has been reached. Moreover, the revised national emission Ceiling Directive (EU, 2016) introduced a ceiling equal to 84% of 2005 emissions for 2030.

Figure 2.3 NH_3 emission trend, percentage share by sector and variation 1990-2023.

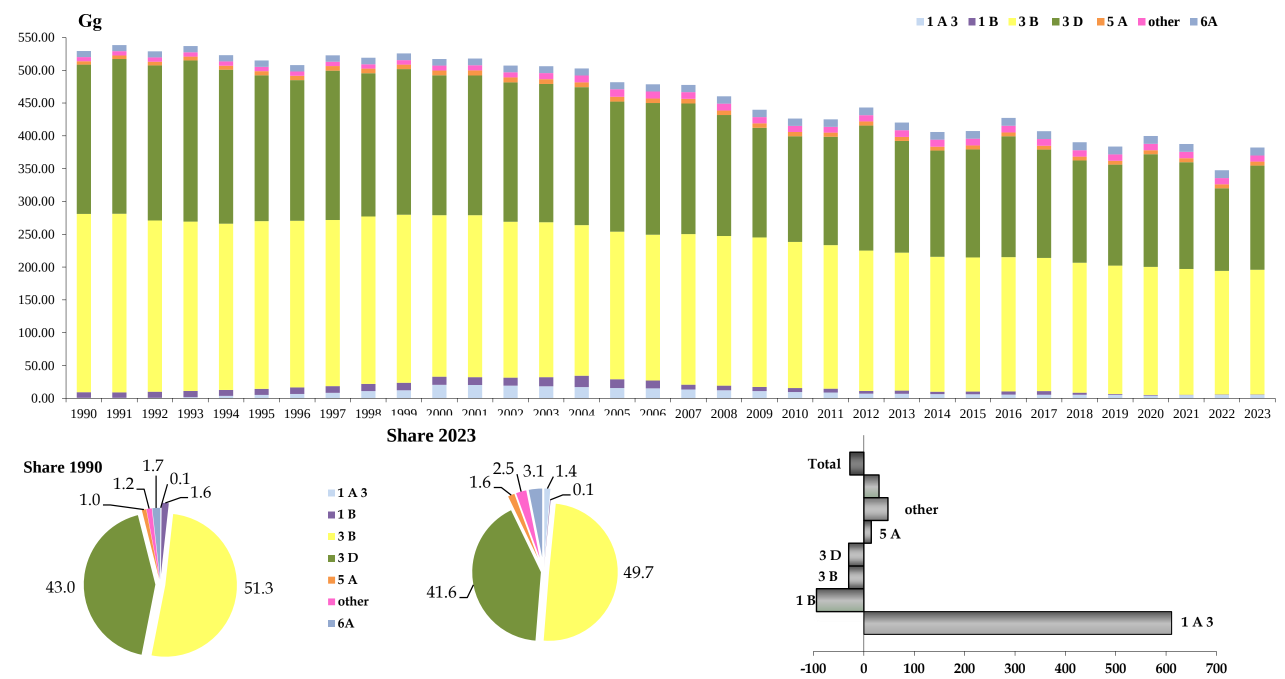


Table 2.3 NH_3 emission trend from 1990 to 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	0.3	0.2	0.2	0.3	0.3	0.3	0.1	0.1	0.2	0.1
Non industrial combustion plants	1.1	1.1	1.0	1.0	1.8	1.6	1.2	1.4	1.3	1.3
Combustion - Industry	0.5	0.6	0.6	4.0	1.6	1.0	1.0	1.2	1.2	1.2
Production processes	0.9	0.5	0.5	0.6	0.6	0.5	0.5	0.3	0.3	0.3
Solvent and other product use	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Geothermal production	8.4	9.0	12.3	13.3	6.0	4.1	0.9	0.4	0.4	0.4
Road transport	0.8	5.3	20.6	15.7	9.6	6.1	4.2	5.0	5.3	5.5
Other mobile sources and machinery	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Waste treatment and disposal	8.1	9.8	11.6	12.0	10.9	12.2	12.3	12.2	12.0	11.9
Agriculture	499.9	478.4	459.9	423.8	384.1	369.5	367.3	354.8	314.7	349.2
Other	9.2	9.7	10.1	10.7	11.4	11.8	12.0	12.0	11.9	12.0
Total	**529.5**	**515.0**	**517.3**	**481.8**	**426.6**	**407.5**	**399.9**	**387.8**	**347.6**	**382.2**

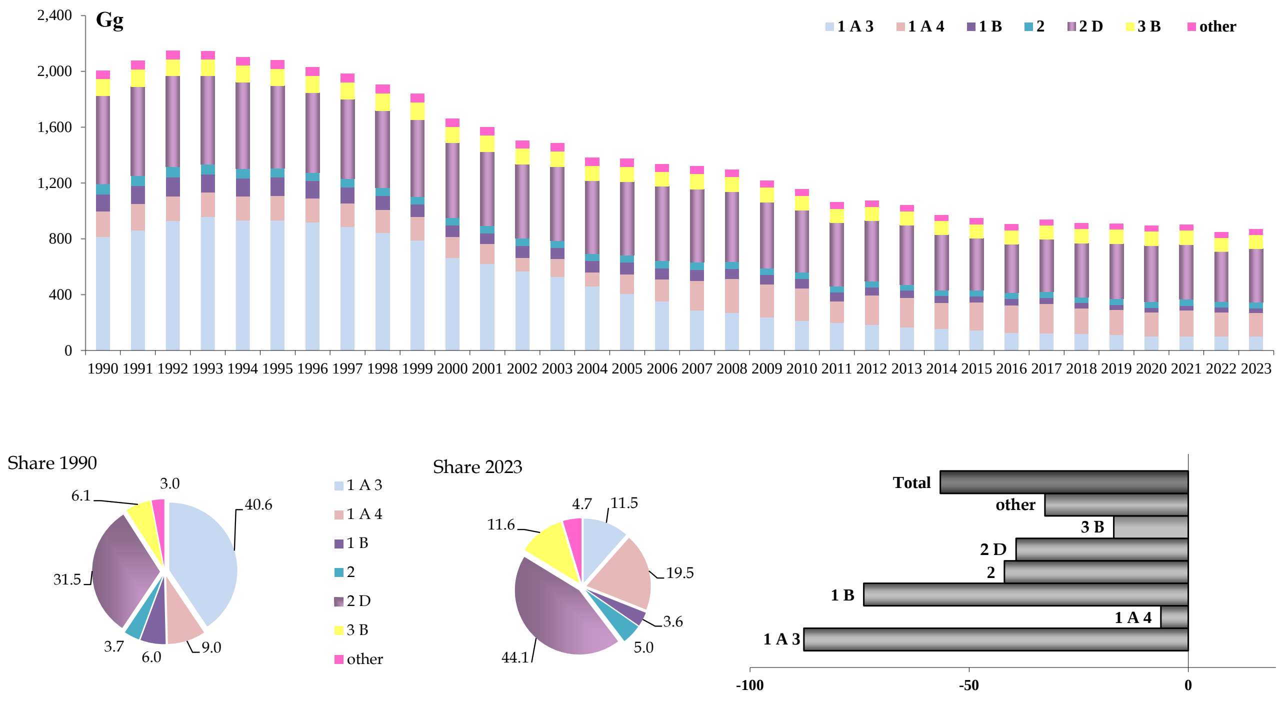
In 2023 agriculture is the main source of emissions, with a 91% contribution out of the total NH_3 emissions; from 1990 to 2023 emissions from this sector show a decrease of about -30%. Emissions from road transport show a strong increase, but the share on the total is 1.4%. Emissions from waste treatment and disposal, accounting also only for 3% of the total, show an increase of about 47% because of the increase of NH_3 emissions from anaerobic digestion at biogas facilities. Emissions from non industrial combustion plants show a relevant increase, equal to 18%, but in 2023 the contribution to total emissions is 0.3%. Emissions from combustion in energy and transformation industries as emissions from combustion in industry are not relevant accounting for 0.03% and 0.3% respectively. Emissions from production processes show a reduction of about -64%, but also this contribution is irrelevant as well as emissions from solvent and other product use. Finally, emissions from geothermal production contribute in 2023 for 0.1% of total national emissions.

Specifically, emissions from agriculture have decreased because of the reduction in the number of animals and the trend in agricultural production, and the introduction of abatement technologies due to the implementation of the EU IPPC Directive (EC, 1996). In the last years further emissions reduction result from the implementation of the European Union Rural Development Programs which provide incentives to the introduction of good practice and technologies for the environmental protection and mitigation of GHG and ammonia emissions. Emissions from road transport have increased as a result of the introduction of catalytic converter but during the last years a decrease is observed due to the introduction of more stringent limits in the new vehicles. Emissions from geothermal production have decreased because of the introduction of control and abatement systems in the production plants. Waste sector trend is driven by the increase of biogas facilities due to the incentives for energy production by renewable sources.

2.1.4 Non methane volatile organic compounds (NMVOC)

The national atmospheric emissions of NMVOC show a decreasing trend in the period 1990-2023. Figure 2.4 and Table 2.4 illustrate the emissions values from 1990 to 2023. Figure 2.4 also illustrates the share of NMVOC emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.4 NMVOC emission trend, percentage share by sector and variation 1990-2023.



The total emission trend shows a reduction of about 57% between 1990 and 2023, from 2,007 Gg to 871 Gg.

In the framework of the National Emission Ceilings Directive (EC, 2001), the target value of NMVOC for 2010 fixed at 1,159 Gg was reached. The target established in the framework of the UNECE/CLRTAP Convention for 2020, equal to 65% of 2005 emission level, has been reached taking into account that it does not include emissions from the agriculture sector apart those from combustion of agriculture residues. In the framework of the European National Emission Ceiling Directive (EU, 2016) a target has been established for Italy equal to 54% of 2005 emissions in 2030.

Solvent and other product use is the main source of emissions, contributing to the total with 44% and showing a decrease of about -39%. The main reductions relate to the road transport sector (-88%), accounting for 10% of the total and to the sector of extraction and distribution of fossil fuels/geothermal energy (-69%), accounting only for 3%. Emissions from agriculture decrease of about 19%, accounting for 14% of the national total. Emissions from other mobile sources and machinery, accounting for 2% of the total, decrease of about 88%. Emissions from non industrial combustion plants show the largest increase (60%), accounting for 19%. Emissions from waste treatment and disposal show a decrease of about -4% while combustion in industry is reduced by 9%; both these sources account only for about 1%. Details on the sectoral emission trend and respective variation are outlined in the following sections.

Table 2.4 NMVOC emission trend from 1990 to 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	7.6	7.4	6.1	5.6	4.9	3.7	3.4	3.5	3.6	3.1
Non industrial combustion plants	102.6	112.6	112.8	121.1	215.3	188.3	164.1	180.8	167.7	164.5
Combustion - Industry	7.2	8.0	8.4	8.4	6.7	6.7	6.1	7.4	7.2	6.6
Production processes	105.2	94.7	79.0	82.0	67.0	51.4	48.2	46.7	43.2	46.6
Geothermal production	90.9	103.7	56.6	53.9	48.6	37.7	28.8	31.4	30.5	28.4
Solvent and other product use	632.9	589.5	533.8	525.4	444.3	371.0	398.7	390.2	359.4	384.1
Road transport	767.0	879.7	612.2	359.1	180.9	127.9	86.4	86.7	90.7	90.6
Other mobile sources and machinery	133.4	122.0	97.9	73.9	51.7	30.1	24.3	21.8	17.5	16.0
Waste treatment and disposal	8.8	10.3	10.6	11.1	9.9	8.5	8.5	8.5	8.4	8.5
Agriculture	151.2	151.3	144.8	133.5	124.9	122.3	124.9	124.3	120.5	122.6
Total	**2,006.9**	**2,079.3**	**1,662.1**	**1,373.9**	**1,154.3**	**947.7**	**893.4**	**901.3**	**848.8**	**871.0**

Solvent and other product use

Emissions from this sector stem from numerous activities such as painting (both domestic and industrial), degreasing and dry cleaning, manufacturing and processing of chemicals, other use of solvents and related activities including the use of household products that contain solvents, such as cosmetics, household products and toiletries. Significant reductions occurred in the nineties by the introduction in the market of products with low solvent content in paints, and the reduction of the total amount of organic solvent used for metal degreasing and in glues and adhesives; furthermore, in many cases, local authorities have imposed abatement equipment in the industrial painting sector and forced the replacement of open loop with closed loop laundry machines even before the EU Directive 99/13/EC (EC, 1999) came into force. In 2020 due to pandemic a strong increase of household products has been registered.

Road transport

The trend of emissions in this sector is characterized by a first stage of reduction in the early eighties, which occurred despite the increase of consumption and mileage because of the gradual adjustment of the national fleet to the European legislation, ECE Regulation 15 and subsequent amendments, introducing stricter emission limits for passenger cars. Subsequently, in the early nineties, an increase in emissions is observed, with a peak in 1992, due to a high increase in gasoline consumption not efficiently opposed by the replacement of the fleet. With the introduction of Directive 91/441/EC (EC, 1991) and following legislation, which provides the use of catalytic device to reduce exhaust and evaporative emissions from cars, NMVOC emissions gradually reduced.

A different explanation of the emission trend pertains to the nineties. In fact, in this period an increase of the fleet and the mileage is observed in Italy, especially for the emergent use of mopeds for urban mobility, which, until 1999, were not subject to any national emission regulation. Thereafter, various measures were introduced in order to facilitate the reduction of NMVOC emissions, including incentives for replacement of both the fleet of passenger cars and of mopeds and motorcycles with low-emission vehicles; incentives were also provided for the use of fuels different from gasoline, such as LPG and natural gas. In addition, funds were allocated for the implementation of urban traffic plans, for the establishment of restricted traffic areas and car-free days, for checks on exhaust pipes of cars, for the implementation of voluntary agreements with manufacturers of mopeds and motorcycles in order to anticipate the timing provided by the European Directive 97/24/EC (EC, 1997 [b]) as regards the placing on the market of mopeds with low emissions.

Non industrial combustion plants

The increasing emission trend is driven by the increase of wood biomass fuel consumption for residential heating. The 2013 consumption value reported in the national energy balance results from a detailed survey conducted by the national institute of statistics in 2014 (ISTAT, 2014) and is much higher than previous estimates. In 2015 the reconstruction backwards of the time series of wood combustion has been finalized with the collaboration of ISTAT and GSE (Energy Services Manager), and official data have been communicated to Eurostat.

Other mobile sources and machinery

The reduction in emissions is explained by the reduction of gasoline consumption in the sector, largely for two-stroke engines used in agriculture and in maritime activities.

Agriculture

NMVOC emissions from agriculture, mainly depend on activity data about different livestock categories. These emissions became significant because of the implementation of the 2016 Guidebook EMEP/EEA emission factors. For the compliance with the established targets these emissions could be subtracted by the total according to the National emission Ceiling Directive (EU, 2016) due to their uncertainty.

As regards the *other sectors*, a decrease in emissions from production processes is observed, mainly in the food industries, in the chemical sector and in the processes in the refineries. The emissions concerning the extraction and distribution of fuels, even in the presence of an increase in quantity treated, have been reduced as a result of the application of the DM 16th May 1996 (Ministerial Decree 16 May 1996), concerning the adoption of devices for the recovery of vapours and of the applications of measures on deposits of gasoline provided by the DM 21st January 2000 (Ministerial Decree 21 January 2000). Emissions from the other sectors are not subject to specific regulations.

2.1.5 Carbon monoxide (CO)

The national CO emissions show a decreasing trend in the period 1990-2023, from 6,824 Gg to 1,849 Gg. The emission figures from 1990 to 2023 are shown in Figure 2.5 and Table 2.5. Figure 2.5 also illustrates the share of CO emissions by category in 1990 and 2023, as well as the total and sectoral variation from 1990 to 2023.

Figure 2.5 CO emission trend, percentage share by sector and variation 1990-2023.

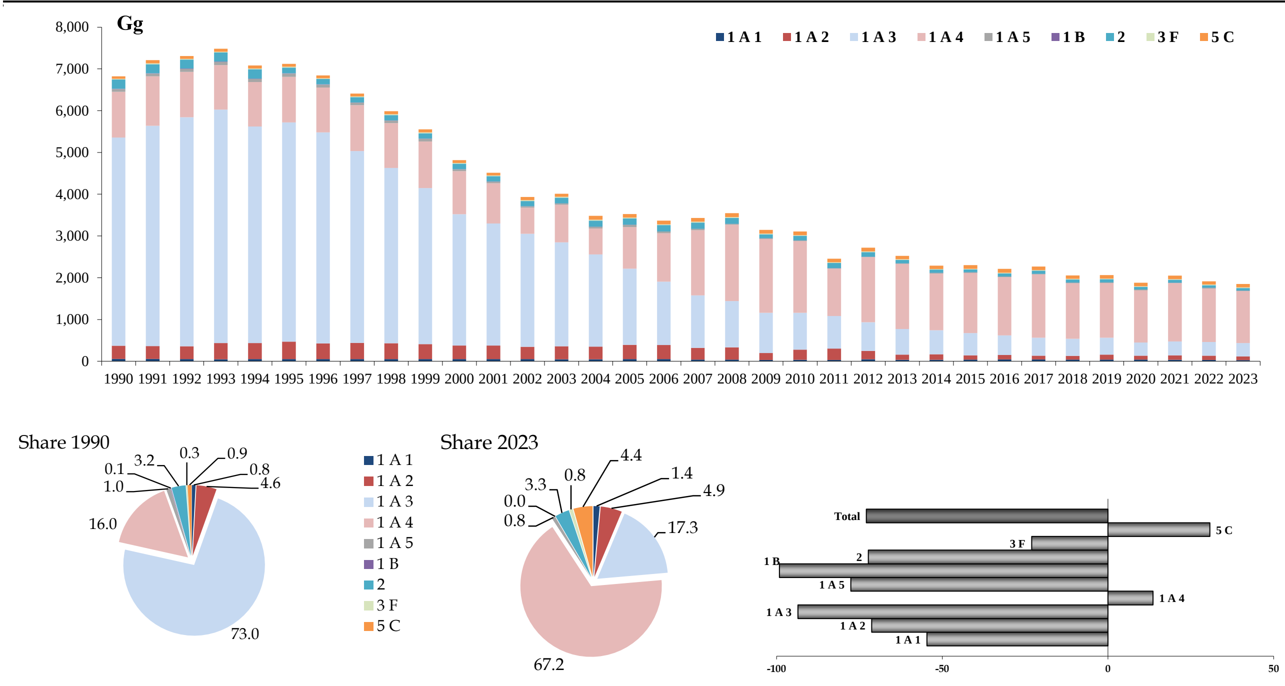


Table 2.5 CO emission trend from 1990 to 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	58.9	54.1	54.4	53.9	34.5	39.9	39.0	34.5	30.9	26.5
Non industrial combustion plants	795.1	894.0	913.1	930.4	1,664.9	1,395.4	1,204.6	1,356.8	1,243.9	1,207.9
Combustion - Industry	305.6	410.9	314.6	326.0	233.6	95.3	88.4	99.9	94.5	84.5
Production processes	223.7	139.8	129.2	143.6	105.0	63.6	56.8	66.0	58.5	56.9
Solvent and other product use	5.1	5.1	5.7	5.3	5.1	4.4	3.9	3.9	3.9	4.1
Road transport	4,874.5	5,126.1	3,009.5	1,693.4	764.7	466.7	258.3	277.7	281.2	274.7
Other mobile sources and machinery	480.5	402.5	303.6	264.0	195.2	133.9	129.6	112.8	109.6	99.7
Waste treatment and disposal	61.7	67.7	65.9	89.0	88.0	88.6	86.2	85.1	77.8	80.7
Agriculture	18.5	18.0	18.1	21.0	15.8	15.3	14.1	14.7	13.6	14.2
Total	**6,823.6**	**7,118.3**	**4,814.0**	**3,526.6**	**3,106.7**	**2,303.2**	**1,880.9**	**2,051.5**	**1,914.0**	**1,849.2**

The decrease in emissions (-73%) is mostly due to the trend observed for the transport sector (including road, railways, air and maritime transport) which shows a total reduction from 1990 to 2023 of about 93%. Specifically, by sector, emissions from road transport and other mobile sources and machinery, accounting in 2023 respectively for 15% and 5% of the total, show a decrease from 1990 to 2023 of about 94% and 79% respectively. On the other hand, emissions from non-industrial combustion plants, representing about 65% of the total in 2023, show a strong increase between 1990 and 2023, equal to 52% due to the increase of wood combustion for residential heating. Figures show an increase in emissions from waste treatment and disposal too (31%), whose share is 4% of the total and a decrease (-23%) for agriculture which accounts for less than 1% of the total.

2.2 PARTICULATE MATTER

2.2.1 PM10

The national atmospheric emissions of PM10 show a decreasing trend in the period 1990-2023, from 346 Gg to 198 Gg. Figure 2.6 and Table 2.6 illustrate the emission trend from 1990 to 2023. Figure 2.6 also illustrates the share of PM10 emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.6 PM10 emission trend, percentage share by sector and variation 1990-2023.

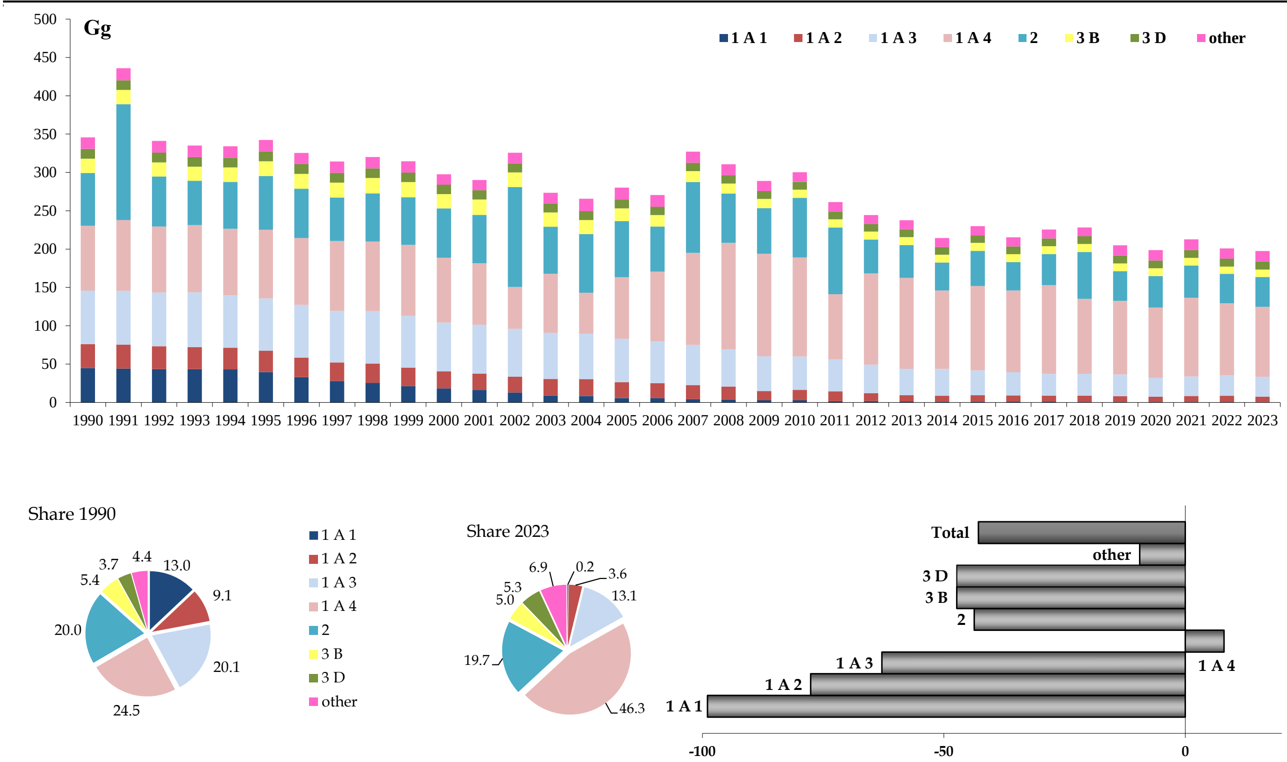


Table 2.6 PM10 emission trend from 1990 to 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	44.8	39.6	18.4	5.9	2.8	1.2	0.6	0.6	0.7	0.5
Non industrial combustion plants	67.8	71.2	68.6	68.6	123.1	106.8	89.9	101.5	93.2	90.6
Combustion - Industry	27.6	25.1	18.6	17.9	12.4	7.7	6.7	7.6	7.9	7.0
Production processes	70.2	70.5	63.7	72.6	76.9	45.2	41.1	41.8	37.9	37.7

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Extraction and distribution of fossil fuels	0.7	0.6	0.6	0.8	0.7	0.6	0.2	0.3	0.4	0.2
Solvent and other product use	5.9	6.1	6.6	7.1	6.6	5.3	6.2	6.5	6.5	7.5
Road transport	59.9	58.9	53.4	47.5	34.7	26.2	16.3	19.1	19.6	19.3
Other mobile sources and machinery	31.6	32.1	30.8	25.3	16.8	10.4	10.8	8.1	8.2	7.7
Waste treatment and disposal	4.8	5.1	5.0	5.4	4.6	5.0	5.7	6.0	5.9	5.8
Agriculture	32.5	33.2	32.0	29.2	21.8	21.4	21.3	21.2	20.7	21.2
Total	**345.8**	**342.4**	**297.7**	**280.3**	**300.4**	**229.9**	**198.8**	**212.7**	**200.9**	**197.6**

From 1990 to 2023 the trend shows a reduction of about 43%. A considerable amount of emissions is mostly to be attributed to non-industrial combustion plant (46% in 2023) which is increasing its emissions, about 34%, due to the increase of wood combustion for residential heating. Emissions from production processes accounting for 19% of the total in 2023 decrease of about -46% between 1990 and 2023. Agriculture sector, accounting for 11% of total emissions in 2023, reduced its emissions by -35% in 2023 with respect to 1990, due to a reduction in emissions from livestock, which fall by about 47%, and a reduction in emissions from crops, which fall by about 17% due to a reduction in the area of arable land in 2023 compared to 1990. Road transport accounts for 10% of total emissions in 2023 and decrease by 68% due to the introduction of the relevant European Directives controlling and limiting PM emissions at the car exhaust pipe. In 2023 other mobile sources and machinery, accounting for 4% of the total, shows a reduction of about 76% in consideration of the implementation of the relevant European Directives on machinery. Emissions from combustion in industry account for about 4% of the total and decrease by about 75%. The largest decrease (-99%) is observed in emissions deriving from combustion in energy and transformation industries, whose contribution to total emissions is almost irrelevant in 2023 and lower than 1%. The reduction in the energy and industrial sectors is mainly due to the introduction of two regulatory instruments, already mentioned for other pollutants, the DPR 203/88 (Decree of President of the Republic of 24th May 1988), laying down rules for the authorization of facilities and the Ministerial Decree of 12th July 1990, which introduces plant emission limits.

2.2.2 PM2.5

The trend of the national atmospheric emissions of PM2.5 is decreasing between 1990 and 2023, with a variation from 236 Gg to 139 Gg. Figure 2.7 and Table 2.7 illustrate the emission trend from 1990 to 2023. Figure 2.7 also illustrates the share of PM2.5 emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.7 PM2.5 emission trend, percentage share by sector and variation 1990-2023.

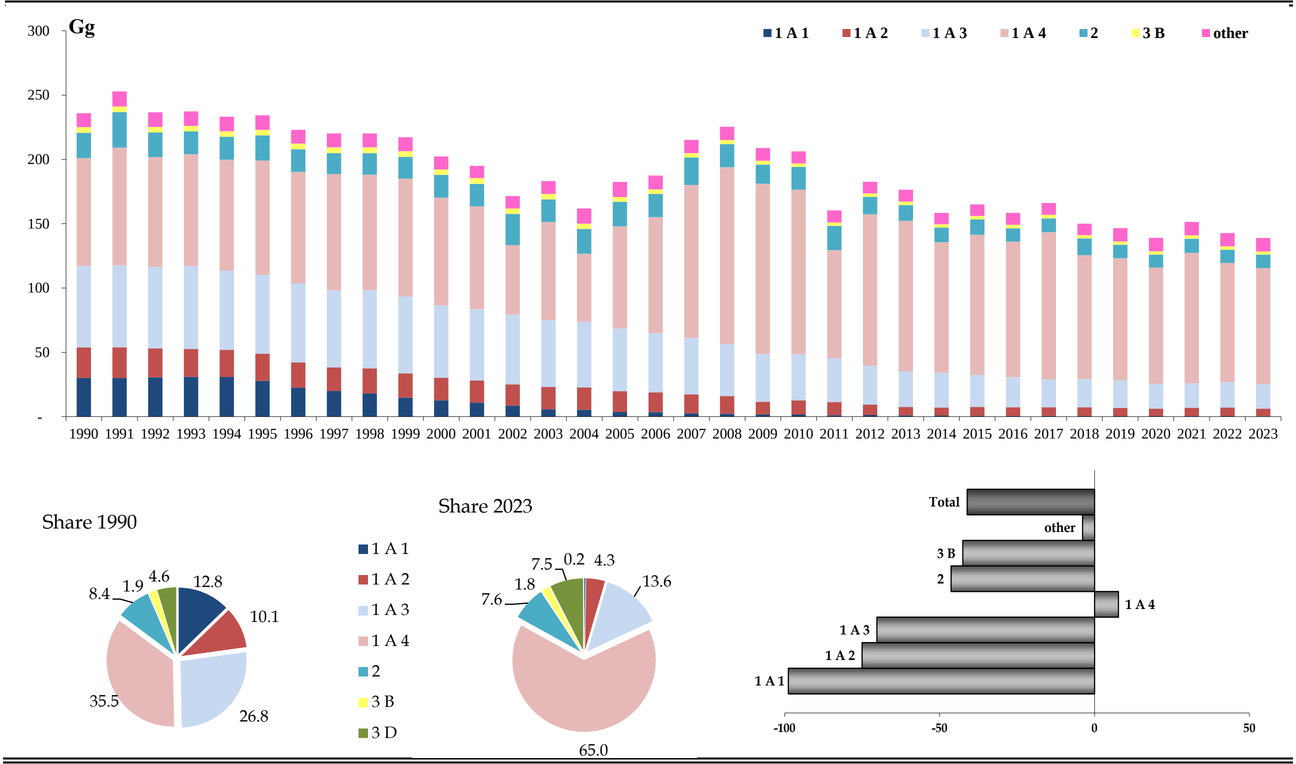


Table 2.7 PM2.5 emission trend from 1990 to 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	30.1	27.8	12.7	3.7	1.8	0.8	0.4	0.4	0.5	0.4
Non industrial combustion plants	66.9	70.5	67.9	67.8	121.8	105.6	88.8	100.2	92.0	89.4
Combustion - Industry	19.9	18.3	14.0	13.6	9.8	6.3	5.6	6.4	6.6	5.9
Production processes	18.2	17.7	15.2	16.6	15.4	10.0	8.4	9.2	8.5	8.4
Extraction and distribution of fossil fuels	0.07	0.06	0.06	0.08	0.07	0.06	0.02	0.03	0.04	0.02
Solvent and other product use	4.7	4.8	5.1	5.4	5.0	4.1	4.6	4.8	4.7	5.4
Road transport	53.7	51.9	45.8	39.3	27.2	18.9	10.8	12.5	12.7	12.3
Other mobile sources and machinery	31.5	32.0	30.7	25.2	16.8	10.4	10.8	8.1	8.2	7.7
Waste treatment and disposal	4.7	5.0	4.9	5.3	4.5	4.9	5.6	5.9	5.8	5.7
Agriculture	6.1	6.0	5.9	5.5	4.1	4.0	3.9	3.9	3.8	3.8
Total	**236.0**	**234.3**	**202.3**	**182.5**	**206.2**	**165.0**	**139.1**	**151.4**	**142.7**	**139.0**

In the framework of the revision of the Multieffect protocol of the UNECE/CLRTAP Convention, a target has been established for this pollutant. Italy should reduce in 2020 their PM2.5 emissions by 10% with respect the 2005 emission level and it has been reached. Moreover, in the national emission Ceiling Directive a target has been established for 2030 equal to 60% of 2005 emissions.

Total emissions show a global reduction from 1990 to 2023 of about 41%. Specifically, emissions from road transport, accounting for 9% of total emissions, decreased about 77%. Emissions from other mobile sources and machinery show a reduction of 76%, accounting for 6% of total emissions in 2023. Emissions from non-industrial combustion plants and from combustion in industry account for 64% and 4% of the total respectively, but while the former shows an increase of about 34%, the latter decreases by about -71%.

Agriculture sector, accounting for 3% of total emissions in 2023, reduced its emissions by 37% in 2023 respect to 1990. Emissions from waste treatment and disposal, accounting for 4% of the total in 2023, show an increase of about 20%. The largest decrease is observed for combustion in energy and transformation industries (-99%), being the influence on the total in 2023 lower than 1%.

For an explanation of the trends see what has already been reported for PM10.

2.2.3 Black Carbon (BC)

Black Carbon emissions have been estimated as a fraction of PM2.5. National BC atmospheric emissions are decreasing between 1990 and 2023, with a variation from 47 Gg to 17 Gg. Figure 2.8 and Table 2.8 illustrate the emission trend from 1990 to 2023. Figure 2.8 also illustrates the share of BC emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.8 BC emission trend, percentage share by sector and variation 1990-2023.

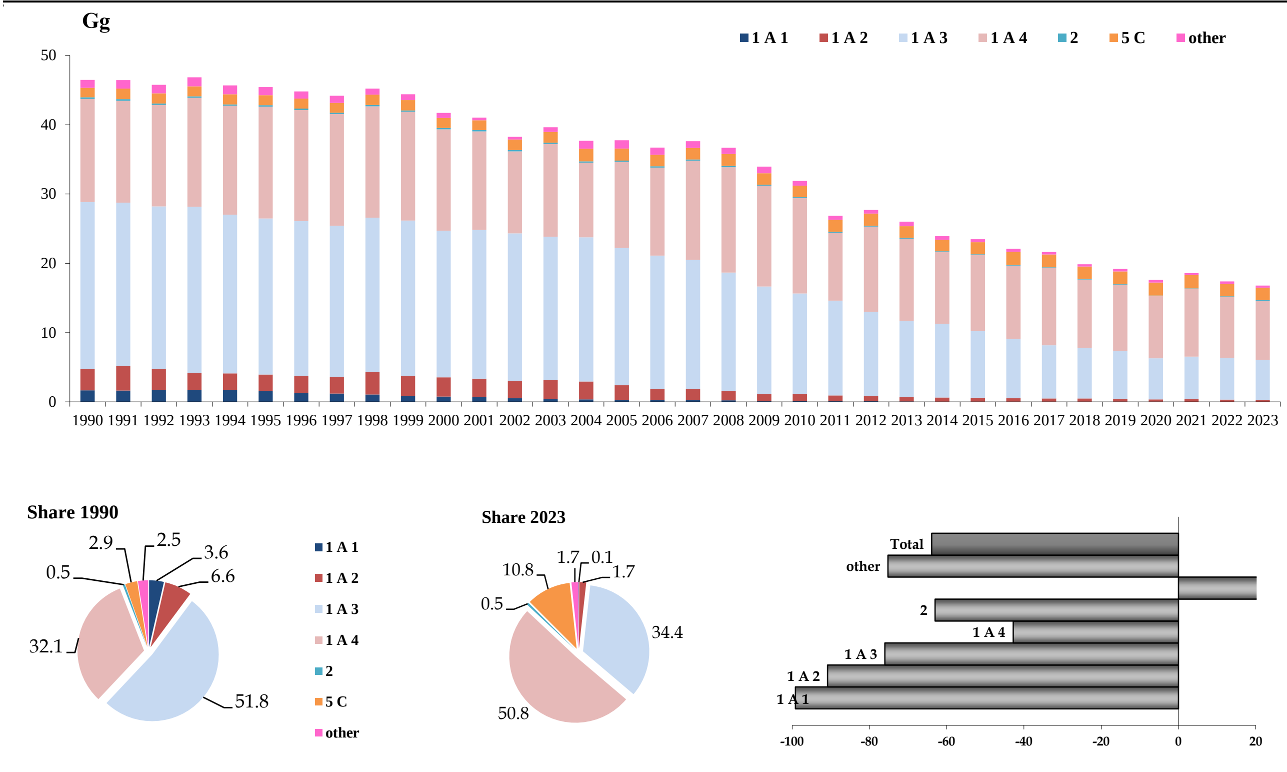


Table 2.8 BC emission trend from 1990 to 2023(Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Combustion in energy and transformation industries	1.7	1.6	0.8	0.3	0.1	0.04	0.03	0.02	0.02	0.01
Non industrial combustion plants	5.4	5.7	5.6	5.7	10.3	9.1	8.0	9.1	8.3	8.1
Combustion - Industry	0.7	0.6	0.5	0.5	0.4	0.3	0.2	0.3	0.3	0.3
Production processes	0.5	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1
Extraction and distribution of fossil fuels	0.1	0.05	0.05	0.1	0.1	0.1	0.02	0.02	0.03	0.02
Road transport	22.6	21.1	19.5	18.2	13.0	8.5	4.1	4.5	4.4	4.1
Other mobile sources and machinery	14.1	14.5	13.6	10.7	6.0	3.6	3.2	2.6	2.3	2.3
Waste treatment and disposal	1.4	1.4	1.4	1.7	1.6	1.8	1.9	1.9	1.8	1.8
Agriculture	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**46.5**	**45.4**	**41.7**	**37.8**	**31.9**	**23.5**	**17.6**	**18.6**	**17.4**	**16.8**

Total emissions show a global reduction from 1990 to 2023 of about 64%. Specifically, emissions from road transport, accounting for 25% of total emissions, decreased of about 82%. Emissions from other mobile sources and machinery show a reduction of 84%, accounting in 2023 for 14% of total emissions. Emissions from non-industrial combustion plants and from combustion in industry account for 48% and 2% of the total respectively, but while the former shows an increase of about 50%, the latter decreases by about 65%. Industrial processes, accounting for less than 1% in 2023, decrease of 78%. Emissions from waste treatment and disposal, accounting for 11% of the total in 2023, show an increase of about 33%. The largest decrease is observed for combustion in energy and transformation industries (-99%), being the influence on the total in 2023, less than 1%.

For the explanation of the trends refer to the previous paragraph.

2.3 HEAVY METALS (PB, CD, HG)

This section provides an illustration of the most significant developments between 1990 and 2023 of lead, cadmium and mercury emissions.

2.3.1 Lead (Pb)

The national atmospheric emissions of lead show a strong decreasing trend (-95%) between 1990 and 2023, varying from 4,302 Mg to 203 Mg. Figure 2.9 and Table 2.9 illustrate the emission trend from 1990 to 2023. Figure 2.9 also illustrates the share of Pb emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.9 Pb emission trend, percentage share by sector and variation 1990-2023.

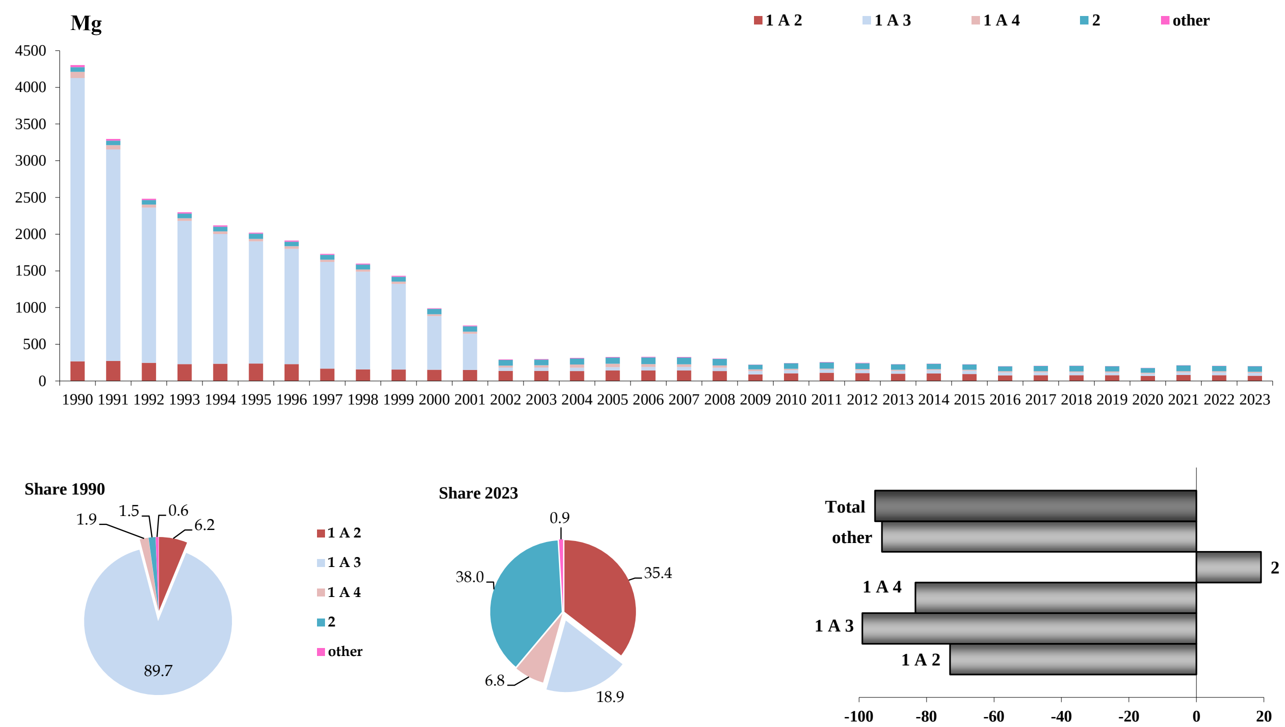


Table 2.9 Pb emission trend from 1990 to 2023 (Mg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Mg				
Combustion in energy and transformation industries	4.0	4.0	3.6	3.8	3.1	2.7	1.4	1.5	1.9	1.3
Non industrial combustion plants	14.5	16.6	22.4	46.3	16.5	15.1	13.6	14.7	13.7	13.7
Combustion - Industry	263.1	234.9	153.6	141.9	104.7	95.0	68.7	80.3	80.0	72.0
Production processes	63.7	68.2	67.3	74.2	69.5	66.1	61.0	72.6	65.3	65.1
Solvent and other product use	2.4	2.4	8.4	10.3	8.4	4.3	3.7	7.2	7.9	12.4
Road transport	3,806.2	1,644.8	719.8	45.7	42.5	42.9	29.4	35.7	37.2	37.3
Other mobile sources and machinery	142.2	44.2	13.3	1.1	1.1	1.1	0.8	0.8	1.2	1.1
Waste treatment and disposal	5.9	5.5	2.8	4.1	0.3	0.2	0.2	0.2	0.2	0.2
Agriculture	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	**4,302.1**	**2,020.6**	**991.2**	**327.3**	**246.1**	**227.5**	**178.8**	**213.0**	**207.3**	**203.2**

In 2023 emissions from combustion in industry have the most significant impact on the total (35%) and show a reduction of about 73%; this reduction is to be attributed primarily to processes with contact, which account for almost the total share of the sector. Emissions from production processes and, in particular, from processes in iron and steel industries and collieries, are not very variable, increasing by about 2% and representing 32% of the total. Emissions from non-industrial combustion plants show a 5% decrease and represent, in 2023, 7% of the total. As to emissions from transport activities, because of changes that have occurred in the legislation regarding fuels, trends show a sharp reduction in emissions from 2002 onwards.

2.3.2 Cadmium (Cd)

The national atmospheric emissions of cadmium show a decreasing trend. Figure 2.10 and Table 2.10 illustrate the emission trend from 1990 to 2023. Figure 2.10 also illustrates the share of Cd emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.10 Cd emission trend, percentage share by sector and variation 1990-2023.

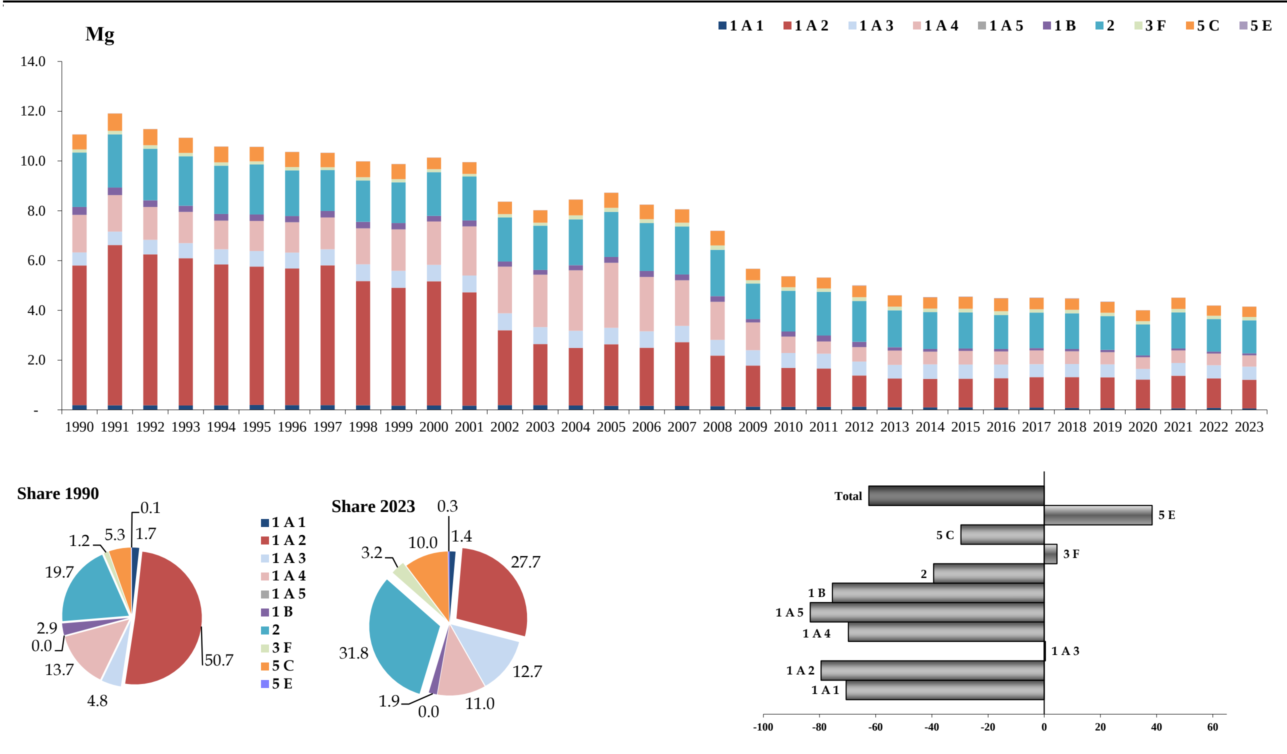


Table 2.10 Cd emission trend from 1990 to 2023 (Mg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Mg				
Combustion in energy and transformation industries	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Non industrial combustion plants	1.5	1.2	1.7	2.6	0.7	0.5	0.5	0.5	0.5	0.5
Combustion - Industry	5.6	5.6	5.0	2.5	1.6	1.1	1.2	1.3	1.2	1.2
Production processes	2.0	1.8	1.4	1.5	1.4	1.1	1.0	1.2	1.0	1.0
Solvent and other product use	0.5	0.5	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.4
Road transport	0.5	0.6	0.6	0.6	0.6	0.6	0.4	0.5	0.5	0.5
Other mobile sources and machinery	0.03	0.03	0.03	0.03	0.03	0.02	0.03	0.02	0.02	0.02

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Mg				
Waste treatment and disposal	0.6	0.6	0.5	0.6	0.4	0.5	0.4	0.5	0.4	0.4
Agriculture	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Total	**11.1**	**10.6**	**10.1**	**8.7**	**5.4**	**4.6**	**4.0**	**4.5**	**4.2**	**4.2**

Emissions show a global reduction of 62% between 1990 and 2023, from 11.1 Mg to 4.2 Mg, mainly driven by the reduction of emissions in the non-ferrous metal industry, with the installation of the relevant abatement technologies and the drop of production. Among the most significant variations, emissions from combustion in industry and from non-industrial combustion plants represent 28% and 11% of the total respectively, showing a decrease of -79% and -70% respectively. Emissions from production processes decreased by about 49% and represent 25% of the total. Emissions from waste treatment and disposal (i.e. waste incineration), accounting for 10% of the total, register a reduction of about -29% while emissions from road transport, accounting for 12% of the total levels, increased by 1% and emissions from stubble burning in agriculture account for 3% of the total and an increase of about 5%.

2.3.3 Mercury (Hg)

The national atmospheric emissions of mercury show a reduction trend in the period 1990-2023. Figure 2.11 and Table 2.11 illustrate the emission trend from 1990 to 2023. Figure 2.11 also illustrates the share of Hg emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Emission trend shows a global reduction of about 65% from 1990 to 2023, varying from 15.3 Mg to 5.6 Mg. The general trend is driven by reduction of emissions in non-ferrous production industry as well as in cement production industry, with the installation of the relevant abatement technologies. The main variations concern: emissions from combustion in industry, accounting for 22% and decreasing by 72%; emissions from production process - processes in iron and steel industries and collieries, representing 52% of the total in 2023 and increasing by 11%; emissions from non-industrial combustion plants which represent 8% of the total and decrease by 28%. Emissions deriving from combustion in energy and transformation industries, accounting for 8%, show a -61% reduction. Emissions from production processes in inorganic chemical industries, not contributing to the total in 2023, show a reduction equal to 100% totally due to the technological changes to produce chlorine. Emissions from road transport account for 4% and are quite stable (+0.8%). Emissions from waste treatment and disposal contributing to the total for 2% show a large reduction, equal to -66% while agriculture, contributing to the total only for less than 1%, is quite stable (+0.1%). Emissions from geothermal production account for 4% of the national total and show a reduction of 94% with respect to 1990 due to the introduction of control and abatement system at the production plants.

Figure 2.11 Hg emission trend, percentage share by sector and variation 1990-2023.

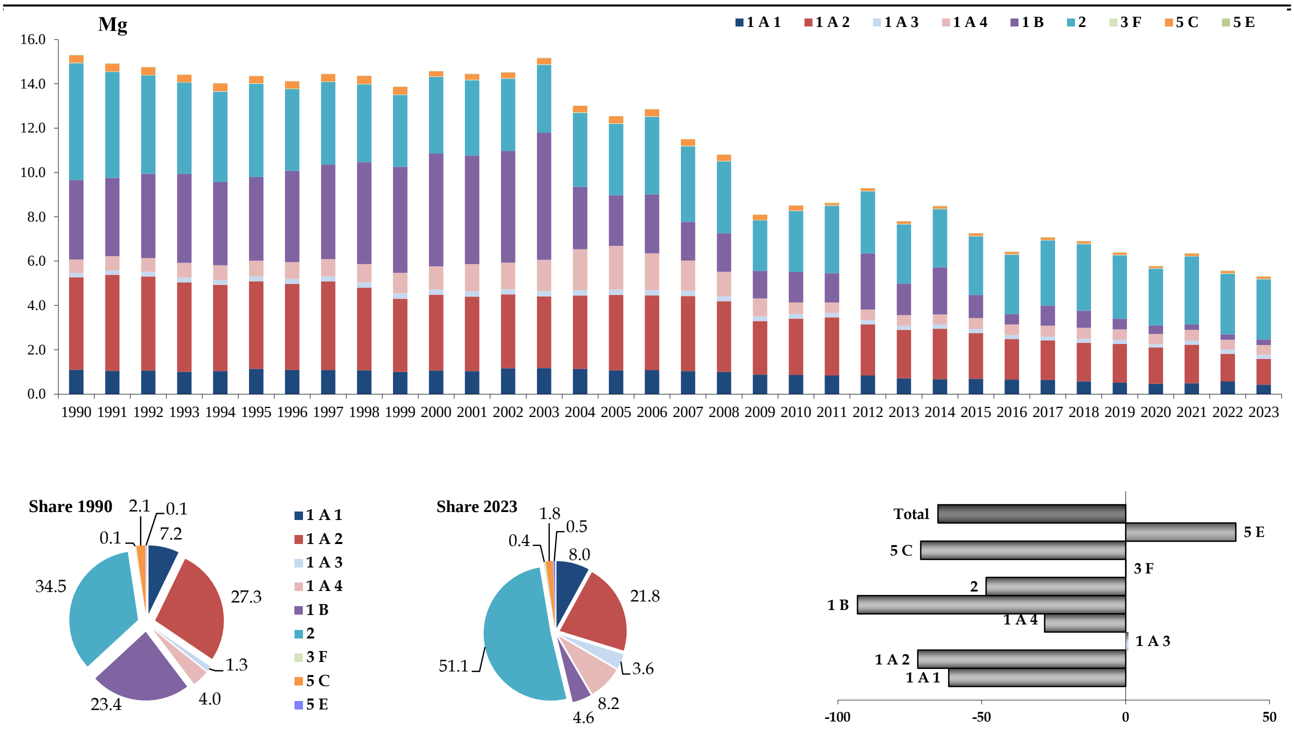


Table 2.11 Hg emission trend from 1990 to 2023 (Mg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
	Mg									
Combustion in energy and transformation industries	1.1	1.1	1.1	1.1	0.9	0.7	0.5	0.5	0.6	0.4
Non industrial combustion plants	0.6	0.7	1.0	2.0	0.5	0.5	0.5	0.5	0.4	0.4
Combustion - Industry	4.2	3.9	3.4	3.4	2.5	2.1	1.6	1.7	1.3	1.2
Production processes	5.5	4.4	3.6	3.4	2.9	2.7	2.6	3.1	2.8	2.8
Geothermal production	3.4	3.6	5.0	2.1	1.3	1.0	0.3	0.2	0.2	0.2
Road transport	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
Waste treatment and disposal	0.3	0.3	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1
Agriculture	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Total	**15.3**	**14.4**	**14.6**	**12.6**	**8.5**	**7.3**	**5.8**	**6.4**	**5.6**	**5.3**

2.4 PERSISTENT ORGANIC POLLUTANTS (POPs)

In this section, the most significant peculiarities of polycyclic aromatic hydrocarbons and dioxins such as HCB and PCB, occurred between 1990 and 2023, will be presented.

2.4.1 Polycyclic aromatic hydrocarbons (PAH)

The national atmospheric emissions of polycyclic aromatic hydrocarbons decreased from 90 Mg to 61 Mg between 1990 and 2023. Figure 2.12 and Table 2.12 illustrate the emission trend from 1990 to 2023. Figure

2.12 also illustrates the share of PAH emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.12 PAH emission trend, percentage share by sector and variation 1990-2023.

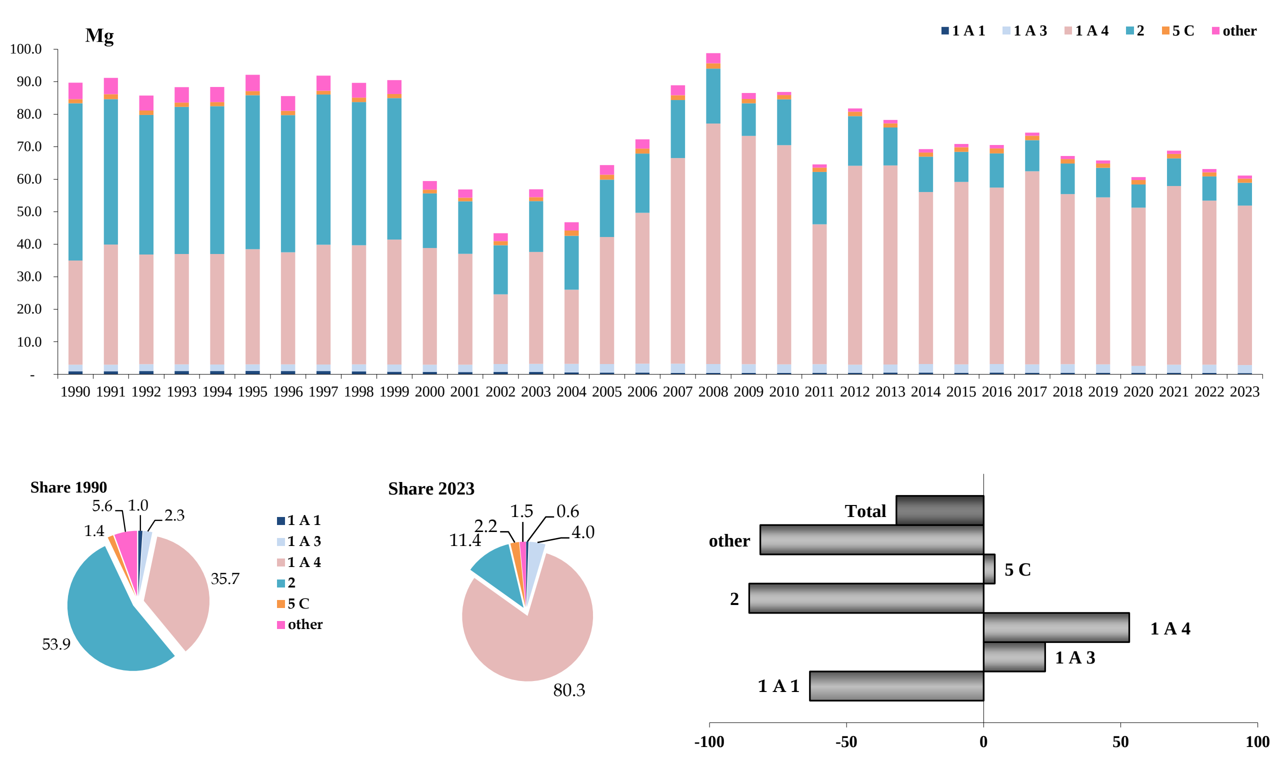


Table 2.12 PAH emission trend from 1990 to 2023 (Mg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Mg					
Combustion in energy and transformation industries	0.9	1.0	0.7	0.5	0.4	0.5	0.5	0.4	0.4	0.3
Non industrial combustion plants	31.9	35.2	35.7	38.9	67.3	55.9	48.6	54.8	50.4	48.9
Combustion - Industry	4.5	4.6	2.2	2.4	0.4	0.5	0.4	0.5	0.5	0.5
Production processes	48.4	47.4	16.8	17.7	14.1	9.3	7.1	8.5	7.4	7.0
Solvent and other product use	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Road transport	1.9	2.0	2.1	2.5	2.6	2.5	2.0	2.4	2.5	2.4
Other mobile sources and machinery	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.2
Waste treatment and disposal	1.3	1.2	1.2	1.5	1.3	1.4	1.4	1.4	1.3	1.3
Agriculture	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Total	**89.7**	**92.1**	**59.4**	**64.3**	**86.8**	**70.9**	**60.7**	**68.8**	**63.1**	**61.1**

Between 1990 and 2023, total emissions show a decrease of about 32%. Among the most significant changes, non-industrial combustion plants, prevalently residential plants, account for 80% of the total in 2023 and show a strong increase (about 54%) due to the increase in wood consumption for heating. Emissions from production processes, mainly processes in iron and steel industries, account for 11% of the total and show a decrease of 86% due to the adoption of best abatement technologies for the coke production; emissions from waste treatment and disposal, mainly open burning of agricultural wastes except stubble burning, account for 2% of the total and show an increase of 4%. Emissions from road transport, accounting for 4% in 2023, show an increase of about 25%. The share of other subsectors is lower than 1%.

2.4.2 Dioxins

The national atmospheric emissions of dioxins show a decreasing trend between 1990 and 2023, with values varying from 529 g I Teq to 297 g I Teq. Figure 2.13 and Table 2.13 illustrate the emission trend from 1990 to 2023. Figure 2.13 also illustrates the share of dioxin emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.13 Dioxin emission trend, percentage share by sector and variation 1990-2023.

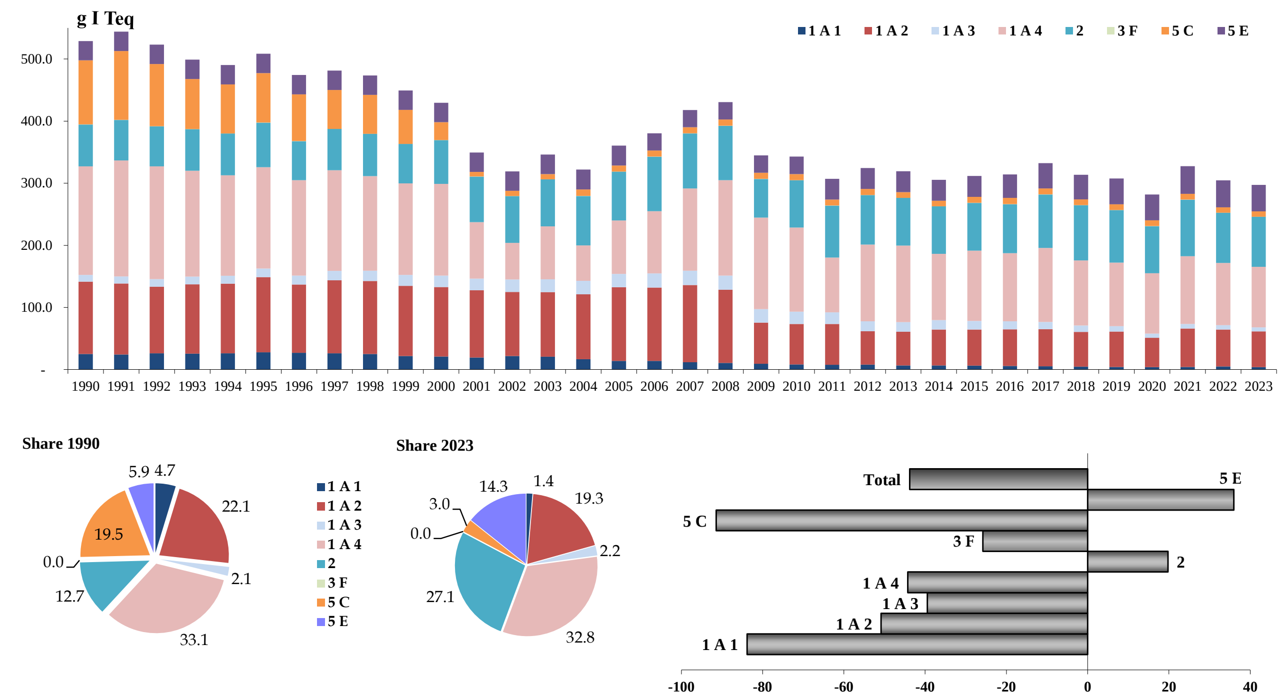


Table 2.13 Dioxin emission trend from 1990 to 2023 (g I Teq)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					g ITeq					
Combustion in energy and transformation industries	24.9	27.9	20.9	14.0	8.2	6.2	4.0	4.1	5.0	4.0
Non industrial combustion plants	173.8	162.0	146.4	84.8	134.6	112.4	96.4	108.5	99.4	96.7
Combustion - Industry	116.7	120.9	112.0	118.7	65.3	58.2	47.1	61.8	59.3	57.3
Production processes	67.2	71.7	70.7	78.6	76.2	76.8	75.7	90.8	80.9	80.5
Solvent and other product use	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Road transport	10.7	13.6	18.2	21.1	19.6	13.7	6.6	7.2	6.9	6.4

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					g ITeq					
Other mobile sources and machinery	1.3	1.4	1.3	1.5	1.2	1.0	1.1	1.0	1.0	0.9
Waste treatment and disposal	134.3	110.7	59.9	41.8	37.8	43.2	50.9	53.8	52.1	51.2
Agriculture	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**529.0**	**508.4**	**429.5**	**360.7**	**342.9**	**311.7**	**281.9**	**327.4**	**304.8**	**297.2**

The general trend shows a decrease from 1990 to 2023 equal to -44%, with a noticeable decline between 1995 and 2004 and between 2008 and 2011 because of the implementation of abatement system in the largest Italian integrated iron and steel plant (steel production > 80% with respect to national production from integrated plants):

- Double filtering system ESP (Electrostatic Precipitator) + MEEP (Moving Electrode Electrostatic Precipitator);
- Reduction of the chlorine amount in the charge;
- Injections of urea (able to form stable compounds with metals that catalyse the formation of dioxins).

The most considerable reductions, between 1990 and 2023, are observed in waste treatment and disposal, combustion in energy and transformation industries and combustion in industry, (-62%, -84% and -51%, respectively). Specifically, the reduction is principally due to the cut of emissions from the combustion of municipal waste both with energy recovery, reported under the non-industrial sector, and without recovery, reported under the waste sector due to the introduction of regulations establishing more stringent limits of dioxin emissions from stacks. The waste sector includes accidental fires of vehicles and buildings which account in 2023 for 14% of total national emissions.

In 2023, the subsectors which have contributed most to total emissions are non-industrial combustion plants, production processes and combustion in industry accounting for 33%, 27% and 19% of the total respectively. Emissions from production processes show an increase of 20% in the period 1990-2023 due to the increase of the iron and steel production in electric arc furnaces.

2.4.3 Hexachlorobenzene (HCB)

The national atmospheric emissions of hexachlorobenzene show a decreasing trend in the period 1990-2023, varying from 142 kg to 12 kg due to the decrease of the use of pesticide in agriculture. Figure 2.14 and Table 2.14 illustrate the emission trend from 1990 to 2023. Figure 2.14 also illustrates the share of HCB emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.14 HCB emission trend, percentage share by sector and variation 1990-2023.

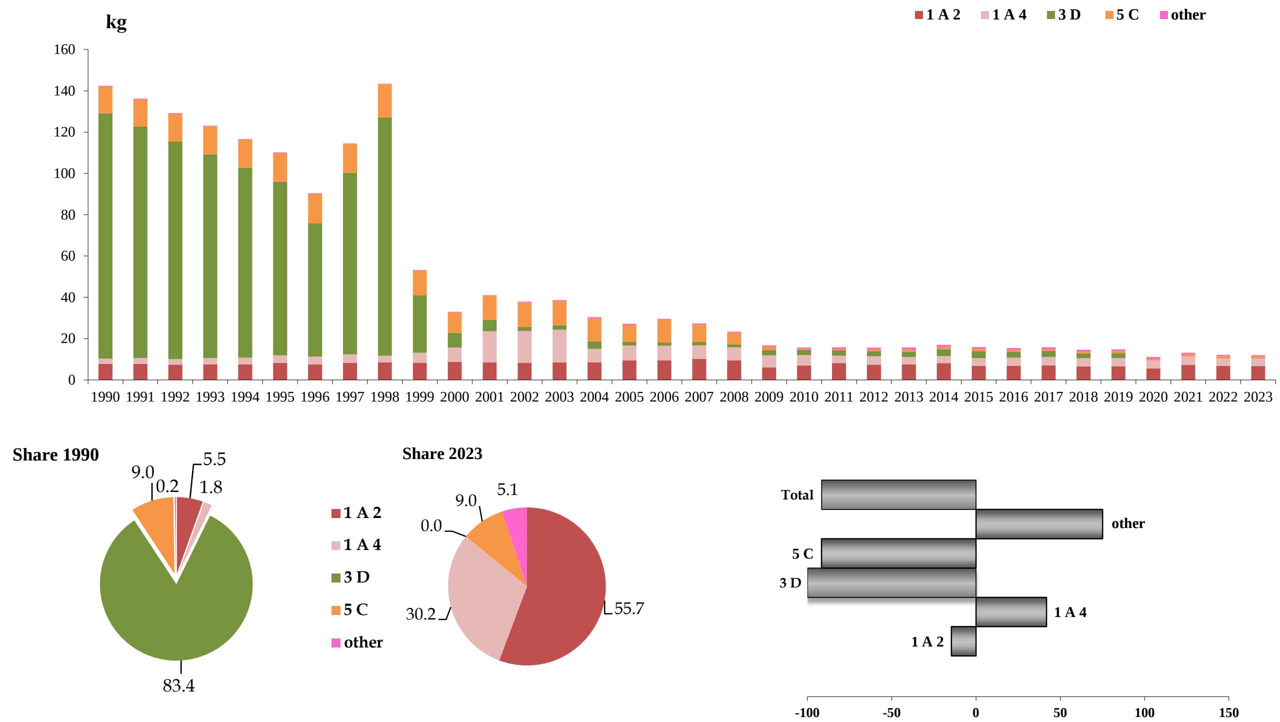


Table 2.14 HCB emission trend from 1990 to 2023 (Mg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Mg				
Combustion in energy and transformation industries	0.0002	0.0002	0.0002	0.0004	0.001	0.001	0.001	0.001	0.001	0.0005
Non industrial combustion plants	0.002	0.003	0.006	0.006	0.004	0.003	0.003	0.004	0.003	0.003
Combustion - Industry	0.008	0.008	0.009	0.009	0.007	0.007	0.005	0.007	0.007	0.007
Road transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00001
Other mobile sources and machinery	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Waste treatment and disposal	0.013	0.014	0.010	0.008	0.000	0.001	0.001	0.001	0.001	0.001
Agriculture	0.119	0.084	0.007	0.002	0.002	0.003	0.000	0.000	0.000	0.000
Total	**0.142**	**0.110**	**0.033**	**0.027**	**0.016**	**0.016**	**0.011**	**0.013**	**0.012**	**0.012**

The use of pesticides in agriculture category is the main driver for the decreasing trend of the HCB national emissions, emissions from this category show 100% decrease between 1990 and 2023. The second sector contributing to the general trend is waste treatment and disposal, in particular waste incineration - sludge incineration. Specifically, the considerable increase in the amount of sludge burnt at a specific incinerator is the reason of the peaks observed in 2001-2003 (incineration with energy recovery). The other relevant sectors are combustion in industry and non-industrial combustion plants accounting for 56% and 26% respectively. Emissions from combustion in energy and transformation industry and emissions from non-industrial combustion plants show an increase of 125% and 68% respectively between 1990 and 2023. In the same years for emissions from waste treatment and disposal a decrease of 92% must be noted while emissions from combustion in industry show a decrease of 15%.

2.4.4 Polychlorinated biphenyl (PCB)

The national atmospheric emissions of polychlorinated biphenyl show a decreasing trend in the period 1990-2023, about -31%, from 154 kg to 106 kg. Figure 2.15 and Table 2.15 illustrate the emission trend from 1990 to 2023. Figure 2.15 also illustrates the share of PCB emissions by category in 1990 and 2023 as well as the total and sectoral variation from 1990 to 2023.

Figure 2.15 PCB emission trend, percentage share by sector and variation 1990-2023.

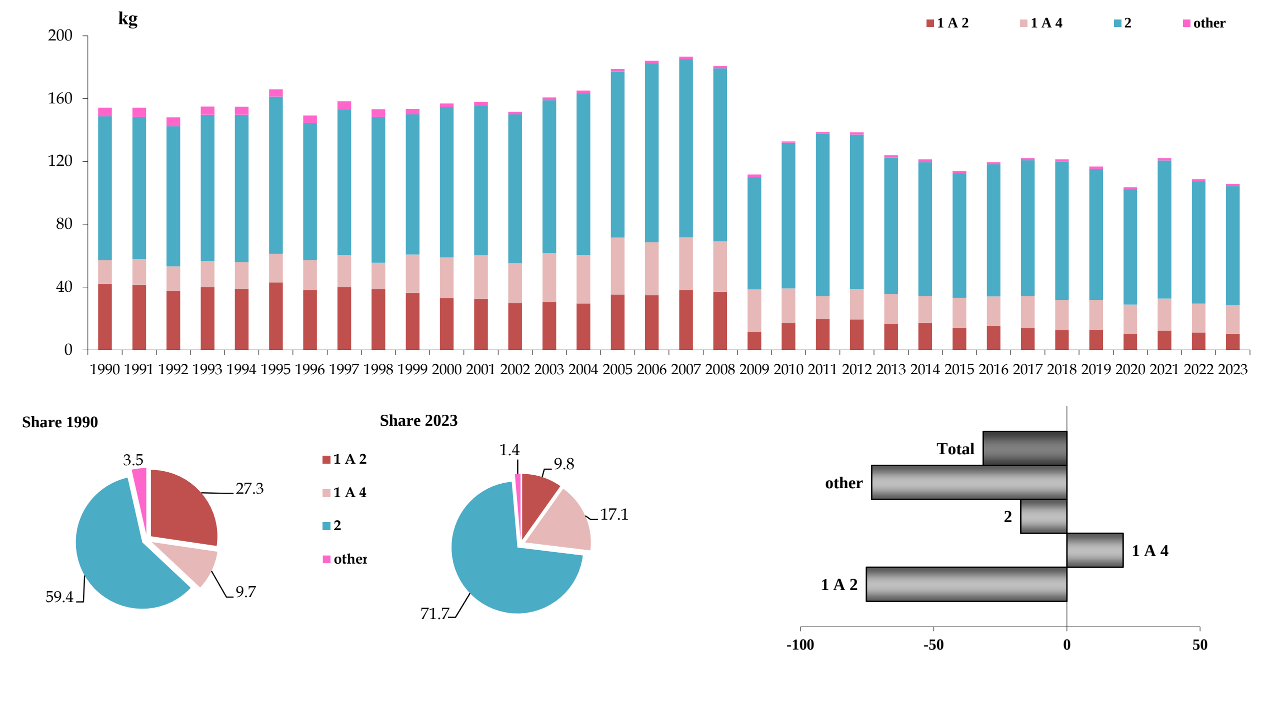


Table 2.15 PCB emission trend from 1990 to 2023 (Mg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Mg					
Combustion in energy and transformation industries	0.00005	0.00004	0.00004	0.0001	0.0002	0.0004	0.0004	0.0004	0.0003	0.0003
Non industrial combustion plants	0.015	0.018	0.025	0.036	0.022	0.019	0.018	0.020	0.018	0.018
Combustion - Industry	0.042	0.043	0.033	0.035	0.017	0.014	0.010	0.012	0.011	0.010
Production processes	0.092	0.100	0.096	0.106	0.093	0.079	0.073	0.088	0.078	0.076
Road transport	0.000003	0.000003	0.000004	0.000004	0.000004	0.000003	0.000001	0.000001	0.000001	0.000001
Other mobile sources and machinery	0.0004	0.0004	0.0004	0.0005	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003
Waste treatment and disposal	0.005	0.005	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001
Total	**0.154**	**0.166**	**0.157**	**0.179**	**0.133**	**0.114**	**0.104**	**0.122**	**0.109**	**0.106**

Among the most significant variations, emissions from combustion in industry and from production processes represent 10% and 72% of the total respectively, showing the former a decrease of -75% and the latter of -17%. The noticeable decline between 2008 and 2009 was due to the implementation of abatement systems in the largest Italian steel plant. The other relevant sector is non industrial combustion plants accounting for 17% and relevantly increasing (22%) between 1990 and 2023. The share of other sectors is about or lower than 1%.

3 ENERGY (NFR SECTOR 1)

3.1 OVERVIEW OF THE SECTOR

For the pollutants and sources discussed in this section, emissions result from the combustion of fuel. All the pollutants reported under the UNECE/CLRTAP are estimated. Stationary and mobile categories are covered for:

- Electricity production (power plants and Industrial producers);
- Refineries (Combustion);
- Iron and steel industries (Combustion)
- Chemical and petrochemical industries (Combustion);
- Construction industries (roof tiles, bricks);
- Other industries (metal works factories, food, textiles, others);
- Road Transport;
- Coastal Shipping;
- Railways;
- Aircraft;
- Domestic heating;
- Commercial heating;
- Public Service;
- Fishing and Agriculture.

Fugitive emissions are also reported under the energy sector as well as emissions from geothermal production.

The national emission inventory is prepared using energy consumption information available from national statistics and an estimate of the actual use of the fuels. The latter information is available at a sectoral level in a different number of publications and different details, such as fuel consumption, distance travelled, or some other statistical data related to emissions. For most of the combustion source categories, emissions are estimated from fuel consumption data reported in the National Energy Balance (BEN) as supplied by the Ministry for the Environment (MASE, several years (a)) and reported to the international energy organization, and from emission factors appropriate to the type of combustion and the pollutant. With the previous submission, a review process of the national energy balance was initiated with Eurostat. In a first step, those responsible for the National Energy Balance implemented methodological changes for 2022 and subsequently applied these changes to 2021 to make it consistent. The review process, carried out in agreement with the relevant international institutions, regards definitions of "main activity producer" and "autoproducer" and the consequent adoption by Italy of these definitions in place of those previously used and linked to Italian legislation. This change in methodology has caused a fairly evident break in the series for some fuels and it is necessary further work to improve the time series consistency.

The estimate from fuel consumption emission factors refers to stationary combustion in boilers and heaters. The other categories are estimated by more complex methods discussed in the relevant sections. The fuel consumption of "Other industries" is estimated so that the total fuel consumption of these sources is consistent with the national energy balance.

Electricity generation by companies primarily for their own use is auto-generation, and the relevant emissions should be reported under the industry concerned. However, national energy statistics report emissions from electricity generation as a separate category. The Italian inventory makes an overall calculation and then attempts to report as far as possible according to the guidelines:

- auto-generators are reported in the relevant industrial sectors of section "1.A.2 Manufacturing Industries and Construction";
- refineries auto-generation is included in section 1.A.1b;
- iron and steel auto-generation is included in section 1.A.1c;
- incinerators auto-generation of energy and heat is included in section 1.A.4a.

These reports are based on estimates of fuel used for steam generation connected with electricity production supplied by the National Independent System Operator (TERNA, several years).

Emissions from the energy production plants in integrated iron and steel plants and emissions from coke ovens are included in 1.A.1c category. Emissions from waste incineration facilities with energy recovery are reported under category 1.A.4a i (Combustion activity, commercial/institutional sector), whereas emissions from other types of waste incineration facilities are reported under category 5.C (Waste incineration). In particular, for 2023, almost 99% of the total amount of urban waste incinerated is treated in plants with an energy recovery system. The energy recovered by these plants is mainly used for district heating of commercial buildings or used to satisfy the internal energy demand of the plants. Different emission factors for municipal, industrial and oils, hospital waste, and sewage sludge are applied, as reported in the waste chapter. Waste amount is then converted into energy content applying the relevant factor as resulting from data provided by TERNA, which in 2023 is equal to 11.1 GJ/t of waste.

Landfill gas is generally recovered and used for heating and power in commercial facilities, the resulting emissions are reported under 1.A.4.a. Biogas recovered from the anaerobic digestion of animal waste is used for utilities in the agriculture sector and relative emissions are reported under 1.A.4.c.

Under 1.A.2 g vii industrial off road machinery are reported; the methodology used to estimate emissions from a range of portable or mobile equipment powered by reciprocating diesel engines is summarized. Industrial off-road include construction equipment such as bulldozers, loaders, graders, scrapers, rollers and excavators and other industrial machines such as portable generators, compressors and cement mixers. Estimates are calculated taking into account especially the population of the different classes, annual usage, average power rating, load factor and technology distribution (EURO) according to the Guidebook (EMEP/EEA, 2019). COPERT II has been used for the years 1994 and 1995 to estimate emissions and average emission factors for vehicles and diesel fuel consumption. Population data has been estimated on the basis on a survey of machinery sales. Machinery lifetime was estimated on the European averages reported in EMEP/CORINAIR, 2007, the annual usage data were taken either from industry or published data by EEA. The emission factors used came from EMEP/EEA and COPERT. The load factors were taken from COPERT. It was possible to calculate fuel consumption for each class based on fuel consumption factors given in EMEP/CORINAIR, 2007. Comparison with known fuel consumption for certain groups of classes suggested that the population method overestimated fuel consumption by factors of 1.2-1.5 for industrial vehicles. Time series is reconstructed in relation to the diesel fuel use in industry reported in the national energy balance as gasoil final consumption. Emission factors for NO_X, CO, NMVOC and PM have been updated taking into account the reduction factors established in the European Directive 97/68/EC, the timing of application of the new limits and the tax of penetration of the new industrial vehicles in the total fleet. Emission reduction factors reported in the European Directive 2004/26/EC Directive have been applied and introduced in the emission estimates.

The emission factors used are based on national sources, or else on values specified in the EMEP/EEA guidebook and/or IPCC guidelines which are appropriate for Italy. Emission factors used for energy and manufacturing industries and non-industrial combustion, specifically categories 1A1, 1A2, 1A4, and their references are available on the ISPRA website at https://emissioni.sina.isprambiente.it/inventario-nazionale/ as well as emission factors for road transport (1A3b) .

In 2023 the energy sector accounts for more than 50% of total emissions for all the estimated pollutants, except for NMVOC, which accounts for 36%, Hg for 46%, Zn for 26%, PCB for 27% and ammonia for 2%. In particular, emissions from the energy sector are 92% of CO and of SO_x, 91% of HCB, 90% for NO_X, 88% of BC, 86% of PAH and 83% of PM2.5 national total emissions.

In 2023, the following categories are key categories for different pollutants: public electricity and heat production (1A1a),petroleum refining (1A1b), stationary combustion in iron and steel industries (1A2a), stationary combustion in non-ferrous metal industries (1A2b), stationary combustion in non-metallic mineral industries (1A2f), road transport categories (1A3b), national navigation (1A3d ii), stationary combustion plants in commercial/institutional (1A4a i) and residential (1A4b i), off-road vehicles in agriculture, forestry and fishing (1A4c ii), fugitive emissions from refining and storage (1B2a iv) .

The same categories are key categories for 1990 and for the trend analysis. In addition, for 1990, stationary combustion in chemical industries (1A2c) for SO_X, mobile combustion in manufacturing industries and construction (1A2g vii) for BC, stationary combustion in other industries (1A2g viii) for SO_X, fugitive emissions from distribution of oil products (1B2a v) for NMVOC, other fugitive emissions from energy production (1B2d) for Hg emissions are also key categories. Finally categories 1A2c, 1B2c for SOx, 1A2c for NOx, 1B2d for NH_3 and 1A2c for PM10 are key categories in trend.

The following sections present an outline of the main key categories in the energy sector. Table 3.1 highlights the key categories identified in the sector.

The energy sector is the main source of emissions in Italy with a share of more than 80% for different pollutants; specifically, for the main pollutants, in 2023 the sector accounts for:

- 92% in national total CO emissions;
- 92% in national total SO_X emissions;
- 91% in national total HCB emissions;
- 90% in national total NOx emissions;
- 88% in national total BC emissions;
- 86% in national total PAH emissions;
- 83% in national total PM2.5 emissions.

Moreover, the sector is also an important source for heavy metals; specifically in 2023, energy sector is responsible for 55% of total Cd emissions, 46% for Hg and 62% for lead emissions.

There are limited differences as compared to the sectoral share in 1990, except for heavy metals, in particular lead whose contribution in 1990 was 98% of total emissions, 36% higher than in 2023, for PAH whose contribution in 1990 was 44%, 42% lower than in 2023 and for HCB emissions with 8% in 1990 against 91% in 2023.

One of the most important sources of emissions in the sector and key category, in 2023, is represented by road transport (1A3b), at least for the main pollutants: NO_X (40.2%), BC (24.7%), Pb (18.4%), CO (14.9%), Cd (12.3%), NMVOC (10.4%) and particulate matter (PM10 9.8%, PM2.5 8.9%). There has been a strong reduction in lead emissions from 1990 to 2023 in road transport due to the replacement of lead gasoline. An in-depth analysis of the road transport category and its emission trends is reported in paragraph 3.5.

Manufacturing industries and construction (1A2) is a main source of heavy metals and POPs, accounting for about 35.4% of lead total emissions, 27.7% for cadmium, 21.8% for mercury, 55.7% for HCB and 19.3% for dioxin. The sector is a key category also for PM10 and PM2.5 (3.5% and 4.2%) as well as SO_X, NO_x and CO, about 32.6%, 7.7% and 4.6% of total emissions. The main sectors are iron and steel sector, which is key for Cd and Hg, the non-ferrous metal sector, key for HCB and Dioxin, and non-metallic mineral sector that is key category for SO_X, NO_X, PM10, PM2.5, Pb, Cd and Hg.

Public electricity and heat production (1A1a) is a key category of SO_X emissions in 2023 with a share of 5.8%, Hg (6.3%) and NO_X emissions (3.7%) while SO_X emissions from petroleum refining (1A1b) is key category in 2023.

National navigation (1A3d ii) is key category for SO_X (11.2%), NO_X (14.9%), PM10 (3.3%), PM2.5 (4.6%), and BC (9.6%). The weight of this category on the total emissions has increased for SO_X and NO_X during the period because of a sectoral delay in the introduction of relevant normative to reduce air emissions.

A sector increasing its level of emissions is the non-industrial combustion (1A4): NO_X and NMVOC, emissions of this category account in 2023 for 18.1% and 19.5% of national total, respectively; SO_X emission account for 12.6%; CO emissions account for 67.2%; Cd emissions account for 11.0%; PM10 and PM2.5 emissions account for 46.3% and 65.0% respectively while BC emissions account for 50.8%; dioxin is 32.8%, PAH is 80.3% , PCB is 17.1% and HCB is 30.2% of national totals. These emissions are prevalently due to biomass combustion in winter, and they are also becoming critical for air quality issues. An in-depth analysis of this category is reported in paragraph 3.12.

Fugitive emissions in refinery from fossil fuel distribution and storage (1B2a iv) is key category in 2023 for SO_X emissions (16.2%). Total SO_X fugitive emissions from distribution of fossil fuels account for 20.3% of the total.

Table 3.1 Key categories in the energy sector in 2023

	1A1a	1A1b	1A1c	1A2	1A3a i	1A3a ii	1A3b i	1A3b ii	1A3b iii	1A3b iv	1A3b v	1A3b vi	1A3b vii	1A3c	1A3d ii	1A3e i	1A4a i	1A4bi	1A4bii	1A4c	1A5b	1B1a	1B1b	1B2
SO_x	5.8	6.3	1.7	32.6	0.5	0.2	0.3	0.1	0.1	0.0				0.0	11.2	0.0	5.9	6.7	0.0	0.1	0.2			20.3
NO_x	3.7	1.5	0.3	7.7	0.9	0.4	19.3	6.4	14.0	0.4				0.1	14.9	0.1	4.9	6.1	0.0	7.1	0.3			1.0
NH_3	0.0	0.0	0.0	0.3			1.3	0.1	0.1	0.0				0.0	0.0		0.0	0.3	0.0	0.0	0.0			0.1
NMVOC	0.2	0.1	0.0	0.8	0.0	0.0	1.5	0.1	0.3	2.8	5.8			0.0	1.0	0.0	3.2	15.5	0.0	0.8	0.1		0.1	3.5
CO	0.9	0.2	0.4	4.6	0.2	0.1	8.8	0.4	1.4	4.3				0.0	2.2	0.0	1.4	63.3	0.0	2.4	0.8			0.0
PM10	0.2	0.1	0.0	3.5	0.0	0.0	1.0	0.3	0.7	0.2		5.2	2.4	0.0	3.3	0.0	0.7	44.9	0.0	0.7	0.2	0.1	0.0	0.0
PM2.5	0.2	0.1	0.0	4.2	0.0	0.0	1.5	0.4	0.9	0.4		3.9	1.8	0.0	4.6	0.0	0.9	63.0	0.0	1.0	0.2	0.0	0.0	0.0
BC	0.0	0.0	0.0	1.5	0.1	0.0	8.4	2.4	5.3	0.5		7.5	0.6	0.0	9.6	0.0	0.8	46.9	0.0	3.0	0.9	0.1	0.1	0.0
Pb	0.5	0.1	0.0	35.4	0.3	0.2	0.0	0.0	0.0	0.0		18.4			0.1		2.5	4.2		0.0	0.0		0.2	0.0
Cd	1.0	0.3	0.0	27.7	0.0	0.0	6.2	0.7	0.7	0.7		4.0		0.0	0.4		2.0	8.6	0.0	0.5	0.0		1.9	0.0
Hg	6.3	1.5	0.2	21.8			2.4	0.4	0.7	0.1							4.0	3.9		0.3			0.9	3.7
PAH	0.5	0.1	0.0	0.8	0.0	0.0	2.5	0.5	0.8	0.1		0.1		0.0	0.1		1.0	78.6	0.0	0.7	0.0		0.0	
Dioxin	0.5	0.8		19.3			1.6	0.2	0.3	0.1					0.1		1.0	31.4		0.4				
HCB	4.2			55.7			0.0	0.0	0.0	0.0					0.9		14.0	12.3		3.9				
PCB	0.3			9.8			0.0	0.0	0.0	0.0					0.1		2.8	14.0		0.3				

Note: key categories are shaded in blue

3.2 ENERGY INDUSTRIES (NFR SUBSECTOR 1.A.1)

This chapter deals with emissions from categories 1A1a Public electricity and heat production, 1A1b Petroleum refining and 1A1c Manufacture of solid fuels and other energy industries.

3.2.1 Methodological issues

Methodologies used for estimating emissions from this sector are based on and conform to the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007; EMEP/EEA, 2013; EMEP/EEA, 2016; EMEP/EEA, 2019; EMEP/EEA, 2023), the IPCC Guidelines (IPCC, 1997; IPCC, 2006) and the Good Practice Guidance (IPCC, 2000). A detailed description on the methods and national specific circumstances as well as reference material of the energy sector is documented in the national inventory report of the Italian greenhouse gas inventory (ISPRA, 2025[a]). The National Energy Balance, published by the Ministry of Environment (MASE), is the main source of information to estimate emissions from the energy sector as it reports fuel consumption for different sectors at national level. Additional information for electricity production is provided by the major national electricity producers and by the major national industry corporation. Other data are communicated by different category associations.

The use of PRTR data has been intensified in recent years, as also described in the following paragraphs. In this regard it should be noted that in response to the review process a survey has been conducted to verify if emission data submitted by operators are calculated subtracting the confidence interval. The issue has been discussed also with the experts from the Ministry of Environment (MASE) in charge of the implementation at national level for the IED legislation. In principle it is to be noted that the validated average values (with the confidence interval subtracted from the measured data) are the data used to verify the compliance of the operators with prescriptions included in the permits issued to the same operators and not for the calculation of the total annual emissions submitted in the framework of the relevant European Union Directives and Regulations. In addition, the implementation at national level of the IED requires Italian operators with emissions reported on the basis of Continuous Monitoring System (CMS) data to refer to confidence intervals which are not those included in the IED: in fact, the confidence intervals must result from quality assurance procedure and the implementation of UNI EN 14181:2005 and QAL2 procedure. This national circumstance implies that the validated average values used by the Italian operators are more realistic compared to those calculated using the procedure laid out in the IED. Moreover, the use of CMS at the stacks is largely implemented at facilities with installations exceeding 50 MWth input. In order to assess consistency along the timeseries, data reported by the largest Italian operator in the energy production (about 25% of energy production) show that no issues concerning consistency can be raised. For consistency issue, official data, as air emission values communicated by the operators in the EU official frameworks, such as the LCP Directive, PRTR registry and IPPC Directive, should be considered as they were reported and without any further adjustment (apart from QA/QC procedures).

Notation key NO for activity is used indicating that a fuel is not consumed at all while NA is reported in the column where is requested to specify a different indicator than fuel consumption.

3.2.1.1 Public Electricity and Heat Production

For 1A1 categories, a Tier 3 is used and SO_X, NO_X and PM10 emissions are estimated on the basis of emission and consumption data provided by the relevant plants in the framework of LCP and ETS European Directives and EPRTR Regulation. The average implied emission factors at fuel level result from the analysis of the information provided and available at plant level, including technologies for energy production and emissions abatement. These IEF at fuel level have been used to estimate emissions for those plants where some pollutants have not been declared and to verify emissions declared. PM 2.5 is estimated applying the ratio between PM2.5 and PM10 reported in the Tier 2 tables of the EMEP/EEA 2019 Guidebook at fuel level.

With regard to heavy metals, country specific emission factors for each fuel have been used to estimate emissions as provided by the main national operator in relation with the technologies in 2001 while for PCB, emission factors for coal, oil products and wood biomass from the EMEP/EEA Guidebook 2019 have been used following the recommendation of the review process (EEA, 2019). Emission factors for the PAH, Dioxin and HCB for Italy are from a study of TNO at European level (Berdowski et al, 1997). A comparison with data from PRTR has been made but in the case of HMs and POPs the information provided in that framework is generally poor and regards only a few plants probably because of the ceiling which is high. For most of the pollutants the available information is not representative of the total. Dioxin, PCB and HCB emissions are generally missing. Gradually, in the next submissions, Italy plans to improve the quality of HMs and POPs estimate on the basis of the figures reported in the PRTR updating the EFs where they are representative of the national total or at least checking the order of magnitude of the values already used when the figures from PRTR are not sufficient to be considered representative of the total. In particular for power plants and coal fueled main plants some HMs under the PRTR are available.

In the following Table 3.2 the main EFs for Public Electricity and Heat production sector are reported. The data shown in the blue cells are country specific emission factors as they are derived from specific measurement campaigns and direct communications by the operators. PM10 EFs too are country specific while PM2.5 EFs have been derived from PM10 EFs and the ratio PM2.5/PM10 per fuel as reported in the EMEP/EEA Guidebook 2019. Finally, Dioxins and PAH EFs come from a study of TNO at European level (Berdowski et al, 1997).

Table 3.2 Main emission factors for Public Electricity and Heat Production - 2023

	SO_x	NO_x	NMVOC	CO	Cd	Hg	Pb	PM2.5	Dioxins	PAH
	g/GJ				mg/GJ			g/GJ		
Steam coal	26.5	35.7	1.5	12.0	0.1	0.9	4.6	0.33	0.0038	0.0000009
Lignite	382.2	35.7	1.5	12.0	0.1	0.9	4.6	0.31	0.0096	0.0000024
Natural gas	0.2	17.5	2.5	20.0	0.0	0.3	0.6	0.01	-	-
Gasoil	14.7	50.0	1.5	12.0	0.1	0.8	2.5	0.05	0.0234	0.0009
Low sulphur fuel oil	29.5	24.2	3.0	15.0	0.1	0.8	2.5	0.77	0.0244	0.0009
High sulphur fuel oil	29.5	24.2	3.0	15.0	0.1	0.8	2.5	0.77	0.0244	0.0009
Other fuel oils	13.2	24.2	3.0	15.0	0.1	0.8	2.5	0.77	0.0244	0.0009
Biomass	3.0	44.8	1.5	12.0				2.10	0.0096	0.0037

3.2.1.2 Refineries

As stated above, for 1A1 categories, a Tier 3 is used and SO_X, NO_X and PM10 emissions are estimated on the basis of emission and consumption data provided by the relevant plants in the framework of LCP and ETS European Directives and EPRTR Regulation. The average implied emission factors at fuel level result from the analysis of the information provided and available at plant level, including technologies for energy production and emissions abatement. These IEF at fuel level have been used to estimate emissions for those plants where some pollutants have not been declared and to verify emissions declared. PM2.5 is estimated applying the ratio between PM2.5 and PM10 reported in the Tier 2 tables of the EMEP/EEA 2019 Guidebook at fuel level. In particular for 1A1b category, the implied emission factor refers both to the production of energy and heat and to the other combustion activities in refineries.

With regard to heavy metals, country specific emission factors for each fuel have been used to estimate emissions as provided by the main national operator in relation with the technologies in 2001 while for PCB, emission factors for coal, oil products and wood biomass from the EMEP/EEA Guidebook 2019 have been used following the recommendation of the review process (EEA, 2019). A comparison with data from PRTR has been made but in the case of HMs and POPs the information provided in that framework is generally poor and regards only a few plants probably because of the ceiling which is high. For most of the pollutants the available information is not representative of the total. Dioxin, PCB and HCB emissions are generally missing. For the next submissions Italy plans to improve the quality of HMs and POPs estimate on the basis of the figures reported in the PRTR updating the EFs where they are representative of the national total or at least checking the order of magnitude of the values already used when the figures from PRTR are not sufficient to be considered representative of the total. For refineries a quite complete reporting is available for selenium and zinc. In the first case the average EFs are very close to the default used while for zinc the resulting EFs from EPRTR is one order bigger than the default used up to now.

In the following Table 3.3 the main EFs for the Refinery sector are reported. The data shown in the blue cells are country specific emission factors as they are derived from specific measurement campaigns and direct communications by the operators. PM10 EFs too are country specific while PM2.5 EFs have been derived from PM10 EFs and the ratio PM2.5/PM10 per fuel as reported in the EMEP/EEA Guidebook 2019. Finally, Dioxins and PAH EFs come from a study of TNO at European level (Berdowski et al, 1997).

Table 3.3 Main emission factors for Refineries - 2023

	SO_x	NO_x	NMVOC	CO	Cd	Hg	Pb	PM2.5	Dioxins	PAH
	g/GJ				mg/GJ			g/GJ		
Combustion plants in refineries										
Refinery gas	0.4	24	2.5	13	-	-	-	5.00	-	-
Kerosene	53	24	3	60	0.14	0.77	2.52	2.50	0.023	0.00036
Petcoke	53	24	1.5	9	0.14	0.77	2.52	4.42	0.029	0.00036
Heavy residual + synthesis gasses	53	24	3	8	0.14	0.77	2.52	7.66	0.024	0.00036
High sulphur fuel oil	53	24	3	10	0.14	0.77	2.52	7.66	0.024	0.00036
Natural gas	0.2	7	2.5	13	0.03	0.31	0.60	0.20	-	-
LPG	0.2	24	2	10	-	-	-	0.20	0.022	-
Refinery furnaces										
LPG	0.2	40	2	10	-	-	-	0.20	0.022	-
Refinery gas	0.4	40	2.5	13.0	-	-	-	5.00	-	-
Kerosene	53	40	3	60	0.14	0.77	2.52	2.50	0.023	0.00036
Gasoline	23	40	3	60	0.14	0.77	2.52	1.25	0.023	0.00036
Gasoil	47	40	3	10	0.14	0.77	2.52	1.25	0.023	0.00036
High sulphur fuel oil	53	40	3	10	0.14	0.77	2.52	7.66	0.024	0.00036
Low sulphur fuel oil	53	40	3	10	0.14	0.77	2.52	7.66	0.024	0.00036
Petcoke	53	40	1.5	9	0.14	0.77	2.52	4.42	0.029	0.00036
No energy fuel	53	40	3	10	0.14	0.77	2.52	7.66	0.024	0.00036

3.2.1.3 Manufacture of Solid Fuels and Other Energy Industries

As already mentioned, for 1A1 categories, a Tier 3 is used and SO_X, NO_X and PM10 emissions are estimated on the basis of emission and consumption data provided by the relevant plants in the framework of LCP and ETS European Directives and EPRTR Regulation. The average implied emission factors at fuel level result from the analysis of the information provided and available at plant level, including technologies for energy production and emissions abatement. These IEF at fuel level have been used to estimate emissions for those plants where some pollutants have not been declared and to verify emissions declared. PM 2.5 is estimated applying the ratio between PM2.5 and PM10 reported in the Tier 2 tables of the EMEP/EEA 2019 Guidebook at fuel level.

In particular, for coke production according to the review (EEA, 2019) PAH emission factors have been disaggregated into those deriving from the combustion process and the fugitive ones and estimated with the emission factors in the Guidebook (EMEP/EEA, 2019).

In the following Table 3.4 the main EFs for the Manufacture of Solid Fuels and Other Energy Industries are reported. The data shown in the blue cells are country specific emission factors as they are derived from specific measurement campaigns and direct communications by the operators. PM10 emission factors too are country specific while PM2.5 have been derived from PM10 and the ratio PM2.5/PM10 per fuel as reported in the EMEP/EEA Guidebook 2019. Finally, Dioxins and PAH emission factors come from a study of TNO at European level (Berdowski et al, 1997).

Table 3.4 Main emission factors for Manufacture of Solid Fuels and Other Energy Industries – 2023

	SO_x	NO_x	NMVOC	CO	Cd	Hg	Pb	PM2.5	Dioxins	PAH
	g/GJ				mg/GJ			g/GJ		
Combustion in coke oven										
Steam coal	27	40	1.5	12	0.15	0.85	4.63	3.50	0.004	0.000001
Natural gas	0.2	7	2.5	20	0.03	0.31	0.60	0.10	-	-
Oxigen furnaces gas	35	82	2.5	13	0.03	0.31	0.60	0.10	-	-
Coke oven gas	35	82	2.5	13	0.03	0.31	0.60	0.10	-	-
Blast furnace gas	35	82	2.5	13	0.03	0.31	0.60	0.10	-	-
High sulphur fuel oil	25	23	3	15	0.14	0.77	2.52	0.10	0.024	0.000890
Coke oven furnaces g/Mg										
Coke production	515	436	146	3920				3		0.008

3.2.2 Time series and key categories

The trend of emissions from energy industries has been influenced by the implementation of the legislative framework and by the evolution and replacement of fuels and these effects can be noticed in particular from the analysis of the NO_x and SO_x trends. The adoption of new regulations, in the late 80s, has led to a shift in energy consumption from oil with high sulphur content to oil with lower sulphur content and to natural gas.

In recent years, the conversion to the use of natural gas to replace fuel oil has intensified, thanks to incentives granted for the improvement of energy efficiency. Furthermore, a significant reduction in the use of coal fuels for energy production has been recorded in the last years. These measures, together with those of promoting renewable energy and energy saving, have led to a further reduction of emissions in the sector. In addition, in the last years, more stringent emission limits to the new plants have been established during the authorization process with the aim to prevent air quality issues at local level.

Until the 2023 inventory submission, Italy had not systematically assessed the uncertainty of national estimates. In 2023 Italy reports NO_X emissions uncertainty assessment (see paragraph 1.8 and Appendix 2), emission categories are disaggregated into a detailed level and uncertainties are therefore estimated for these categories. In addition, Italy has decided to achieve an in-depth analysis of the most important categories for which punctual data are available starting from the NO_X emissions of the thermoelectric power plants (1A1 and 1A2). On the basis of plant by plant consumptions and emissions data reported in the framework of E-PRTR and LCP registers, it has been possible to estimate uncertainty by fuel for natural gas (108 plans), coal (7 plants) and biomass (18 plants). The methodology consists in calculating, for each plant whose activity data and emissions are available, the weighted deviation based on fuel consumptions and emissions. Calculating sigma as the square root of the normalized sum of deviations and considering the average emission factor and the number of plants it is possible to obtain the uncertainty for the considered plants. The consequent results are: for natural gas uncertainty equal to 1.2%, for biomass the uncertainty is equal to 5.3% and for coal equal to 9%.

3.2.2.1 Public Electricity and Heat production

This paragraph refers to the main electricity producers that produce electricity for the national grid. From 1998 onwards, the expansion of the industrial cogeneration of electricity and the split of the national monopoly have transformed many industrial producers into "independent producers", regularly supplying the national grid. These producers account in 2023 for 90.3% of all electricity produced with combustion processes in Italy (TERNA, several years).

In 2023, Public Electricity and Heat production is a key category for SO_x, NO_x and Hg.

Public electricity and heat production (1A1a) is a key source of SO_X emissions in 2023 with a share of 5.8%, Hg (6.3) and NO_X emissions (3.7%). A strong reduction of SO_X, NO_X and PM10 emissions is observed for this category along the time series (as well as for 1A2 sector). The introduction of two regulatory instruments: the DPR 203/88 (Decree of President of the Republic of 24th May 1988), laying down rules concerning the authorization of plants, and the Ministerial Decree of 12th July 1990, which introduced plant level limits to emissions of PM10, NO_X and SO_X for new plants and required old plants to conform to the limit by 1997, explained the emission reduction in the nineties. The shift from fuel oil to natural gas combined with the increase of energy efficiency of the plants and the introduction of PM10 abatement technologies have been implemented to comply with the emission limit values. From 2000 lower limits to emissions at the stacks have been introduced, in the framework of environmental integrated authorizations, for the authorization of new plants and the implementation of the old ones, especially for those facilities located in areas with air quality critical values. For this reason, the plants have increased the use of natural gas heat and power combined technology. In 2023 in Italy there are still 6 coal plants, and 1 fuel oil plant out of around 200 power plants included in this source category. With the exception of few biomass plants and some gasoil stationary engines in the small islands, the other plants are natural gas combined cycle thermoelectric power plants.

3.2.2.2 Refineries

This subsector covers the energy emissions from the national refineries (13 plants in 2023), including the energy used to generate electricity for internal use and exported to the national grid by power plants that directly use off-gases or other residues of the refineries. These power plants are generally owned by other companies but are located inside the refinery premises or just sideways. In 2023 the power plants included in this source category have generated 8.0% of all electricity produced with combustion processes in Italy.

Petroleum refining (1A1b) is a key category for SO_X in 2023. In addition, for 1990, petroleum refining (1A1b) is a key category for SO_X and PM2.5 and in trend for PM10. Emissions are estimated on the basis of emission and consumption data provided by refineries in the framework of LCP, ETS European Directives and EPRTR Regulation and refer both to the production of energy and heat and to the other combustion activities in the plants. Emission trends are driven by the same legislation quoted for 1A1a category, where specific rules and ceiling were set up for refineries.

3.2.2.3 Manufacture of Solid Fuels and Other Energy Industries

In this section, emissions from power plants, which use coal gases, are also reported. In particular, data refers to the electricity generated in the iron and steel plant sites (using coal gases and other fuels). In 2023 the power plants included in this source category have generated about 1.8% of all electricity produced with combustion processes in Italy.

Manufacture of Solid Fuels and Other Energy Industries (1A1c) is not a key category in 2023. Emissions show a decreasing trend linked to a reduction in activity data (only 2 plants remaining in 2023) and to the implementation of abatement technologies and the plants revamping. About abatement technologies, the largest integrated plant in Italy (and in Europe), in the last ten years, has carried out several interventions on the coking plant in the framework of the IPPC permit, applying BAT in several cases.

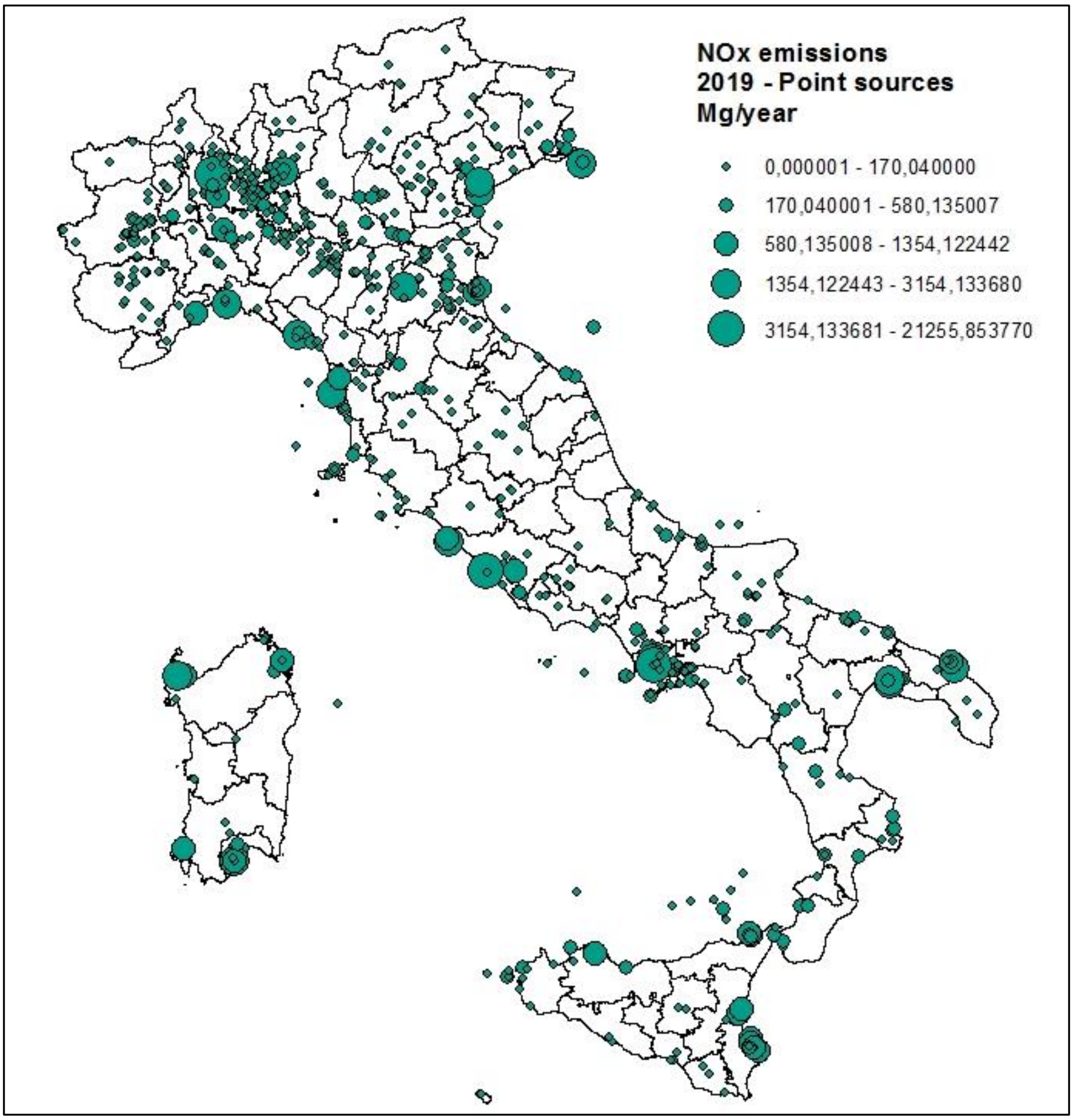
3.2.3 QA/QC and verification

A complete description of methodological and activity data improvements is documented every year in a QA/QC plan (ISPRA, 2025[b]).

The analysis of data collected from point sources allowed to distribute emissions at local level, for 2019 and previous years, as submitted under the CLTRAP. To illustrate an example, NO_X emissions from point sources are reported in for the year 2019. Point sources include public electricity and heat production plants and stationary combustion plants in manufacturing industries and construction.

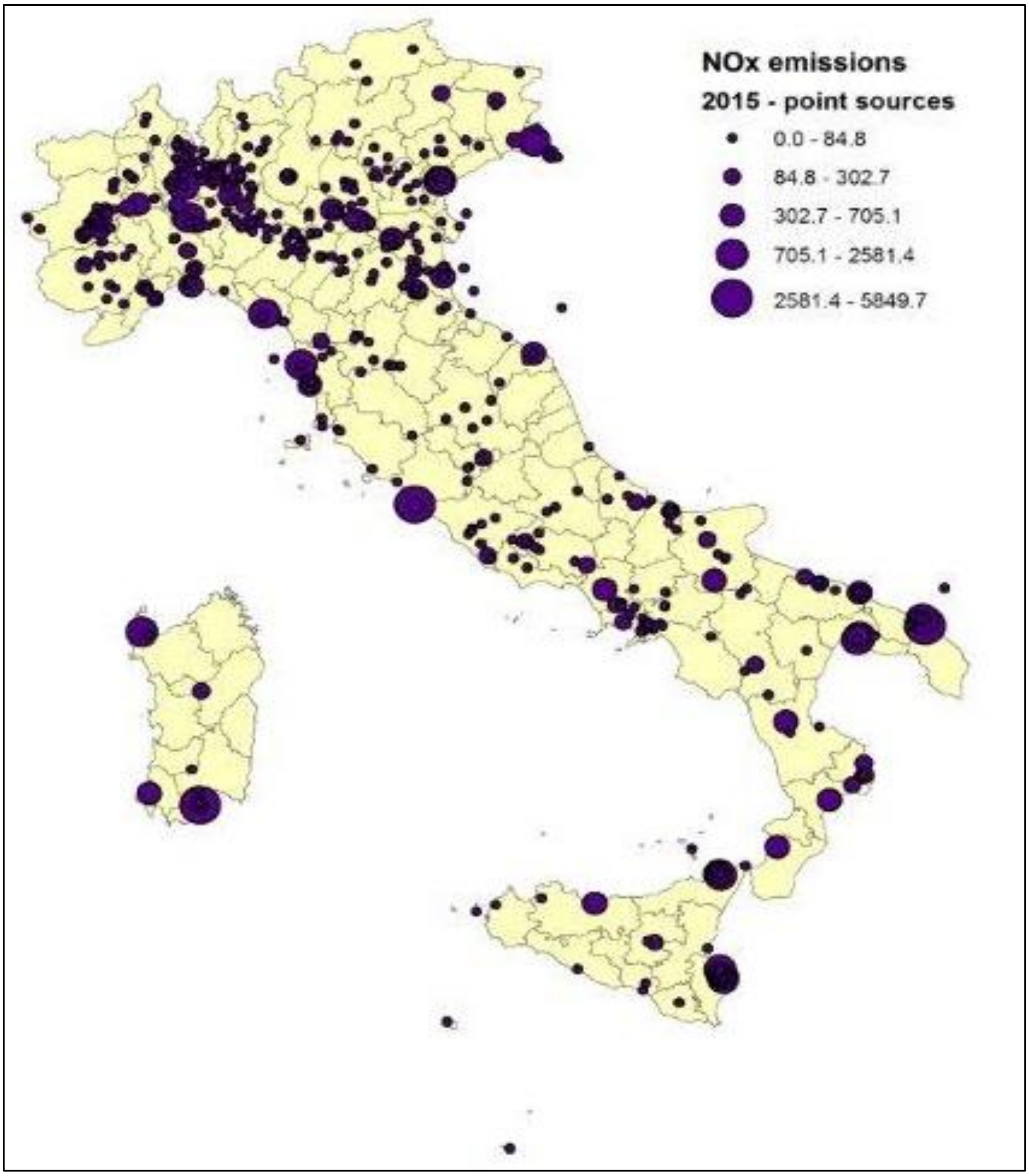
The figure highlights that the most critical industrial areas are distributed in a few regions. The visualization of the following maps created for the disaggregation of 2019, 2015 and 2010 demonstrates how information and data collection have been improved. More information in chapter 10 and in the relevant publications (ISPRA, 2009; ISPRA, 2022). The disaggregation of national emissions for the year 2023 is currently being implemented.

Figure 3.1 NOX emissions from point sources in 2019 (t)



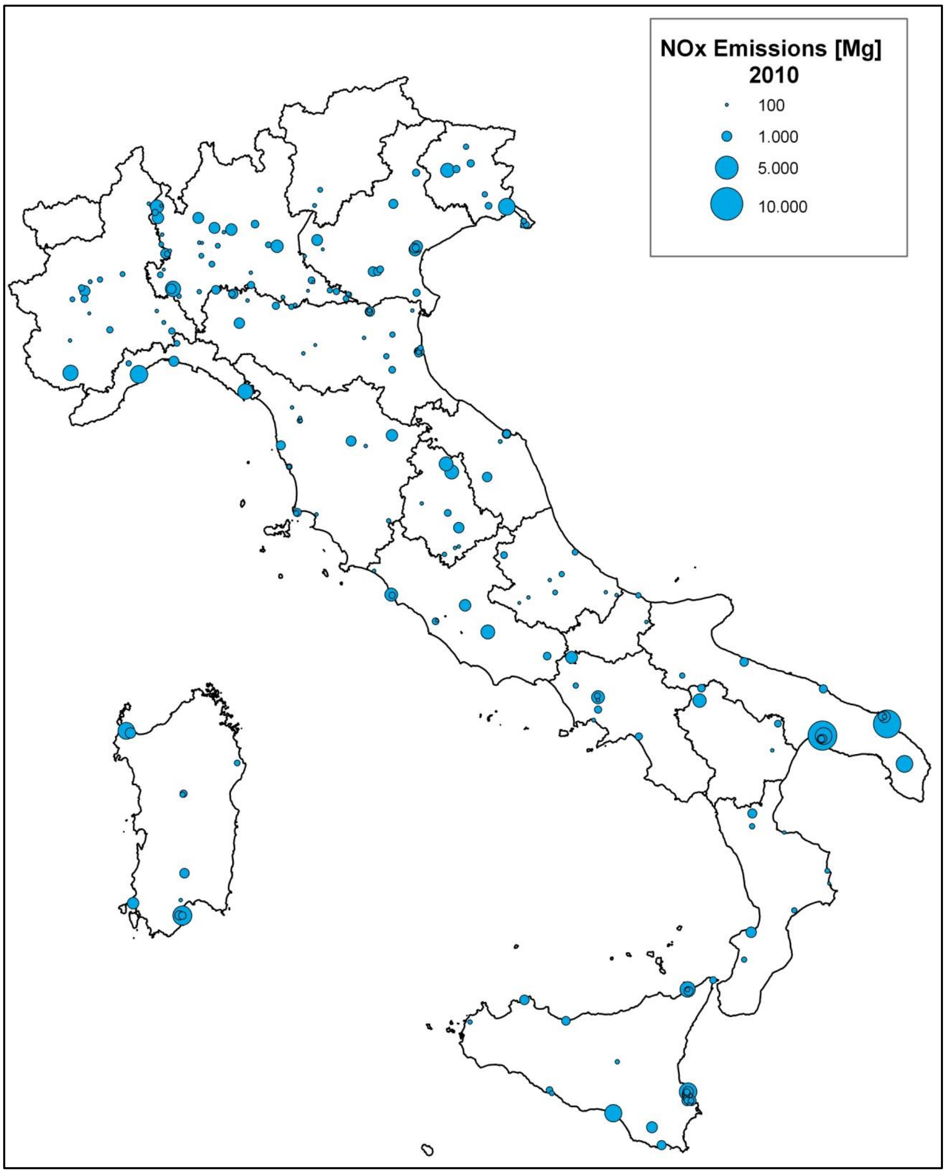
Similarly, in Figure 3.2 NO_X emissions from point sources in 2015 are reported.

Figure 3.2 NOX emissions from point sources in 2015 (t)



In Figure 3.3, NO_X emissions communicated by 229 facilities (power plants, refineries, cement plants and iron and steel integrated plants), in the framework of the national E-PRTR register and LCP Directive, have been processed and geographically located. The territorial distribution shows similar results to those reported in the previous figure highlighting the industrial areas still in activity in 2010.

Figure 3.3 NO_X emissions from point sources in 2010 (t)



3.2.4 Recalculations

In the 2025 submission no recalculations occurred.

3.2.5 Planned improvements

Specific improvements are detailed in the 2025 QA/QC plan (ISPRA, 2025[b]).

For the energy sector, a major progress regards the management of the information system where data collected in the framework of different obligations, Large Combustion Plant, E-PRTR and Emissions Trading, are gathered together thus highlighting the main discrepancies in information and detecting potential errors. Moreover, the complete use of the energy data provided by the Ministry of Environment to the Joint Questionnaire IEA/OECD/EUROSTAT is planned in substitution of the national energy balances used till now; liquid, gaseous and solid fuel are now aligned for the whole time series and renewable fuels and biomass too have been used as possible.

Currently, a review process of the national energy balance is underway with the national energy experts. In this framework, it is planned the integration, where possible, of fuel consumption data reported under the ETS in the National Energy Balance.

With respect to PM10 and heavy metals emissions from Public Electricity and Heat Production category (1A1a) while PM10 emissions are updated every year on the basis of data submitted by the plants in the framework of the EPRTR registry heavy metals emission factors time series have been reconstructed from 1990 to 2001 on the basis of a study conducted by ENEL (major company in Italy). Further work is planned to update/change emission factors for those pollutants where figures reported in the EPRTR lead to average values significantly different from those currently used.

3.3 MANUFACTURING INDUSTRIES AND CONSTRUCTION (NFR SUBSECTOR 1.A.2)

This chapter deals with emissions from Stationary combustion in manufacturing industries and construction, in particular from categories 1A2a Iron and steel, 1A2b Non-ferrous metals, 1A2c Chemicals, 1A2d Pulp, Paper and print, 1A2e Food processing, beverages and tobacco, 1A2f Non-metallic minerals, 1A2g Other.

3.3.1 Methodological issues

For 1A2 categories, estimates for chemical, food processing, and other sectors (as textile, mechanics, extraction) are based on fuel consumption where EMEP/CORINAIR and then EMEP/EEA emission factors at fuel level have been used except for SO_X, NO_X and PM10 which are estimated on the basis of emission and consumption data provided by the relevant plants in the framework of LCP and ETS European Directives and EPRTR Regulation. PM 2.5 is estimated applying the ratio between PM2.5 and PM10 reported in the Tier 2 tables of the EMEP/EEA 2019 Guidebook at fuel level. Emissions of NH_3 have been also included when available at plant level. With regard to heavy metals, country specific emission factors for each fuel have been used to estimate emissions as provided by the main national operator in relation to the technologies, while for PCB emission factors for coal, oil products and wood biomass from the EMEP/EEA Guidebook 2019 have been used following the recommendation of the review process (EEA,2019). Emission factors for the PAH, Dioxin and HCB for Italy are from a study of TNO at European level (Berdowski et al, 1997). For the iron and steel, non-ferrous metal, pulp and paper and non-metallic minerals sectors emission estimates are based on production data at SNAP category level. SO_X, NO_X and PM10 emission factors time series are estimated based on the communication from operators in the framework of LCP Directive and EPRTR Regulation and industrial association at SNAP activity code level. For NMVOC, default EFs of EMEP/CORINAIR 2007 Guidebook are prevalently used except for glass and lead production where country specific emission factors are used; emission factors provided in the EMEP/EEA 2019 Guidebook are not appropriate because they are calculated for small combustion boilers while emissions in this category refer prevalently to boilers >20 MWt for auto-production of energy and heat in the industrial sectors.

The Institute, specifically the same unit responsible for the inventory, also collects data in the context of the European Emissions Trading Scheme, the National Pollutant Release and Transfer Register (Italian PRTR) and the Large Combustion Plants (LCP) Directives. All this data is managed and used to compile the inventory. Figures are cross checked to develop country-specific emission factors and input activity data; whenever data cannot be straight used for the inventory compilation, it is considered as verification. EPER/EPRTR data are yearly available from 2002 while ETS data from 2005 and LCP data from 1990 all on a yearly basis. In the EPRTR registry total emissions divided by category are reported by plants if they exceed the relevant ceiling for each pollutant. LCP data refer only to SO_X, NO_X and PM emissions that are collected in stacks over 50 MWth and could result in figures lower than those reported in the EPRTR. In the ETS only CO_2 and fuel consumption data are reported. QA/QC checks at plants level are directed to check the submissions of data in different contexts and evaluate the differences if any. For example, if emissions submitted by a plant under LCP are higher than those submitted under the EPRTR, ISPRA asks the operator of the reporting plant for an explanation and the verification of data submitted. In addition, on the basis of fuel consumption supplied under the ETS and average emission factor by fuel the energy experts estimate emissions at plant level and compare them with those submitted in the EPRTR and LCP. Also in this case, ISPRA ask for clarifications to the reporting plant if necessary.

3.3.1.1 *Iron and steel*

More in detail 1A2a includes combustion activities from the iron and steel sector such as blast furnace cowpers, sinter plants and reheating furnaces. In 1990 there were four integrated iron and steel plants in Italy. In 2023, there is only one of the above-mentioned plants; oxygen steel production represents about 14% of the total production and the arc furnace steel the remaining 86% (FEDERACCIAI, several years). In 2023, Italy confirmed itself as the first European producer of cast steel from electric furnaces in absolute terms, contributing over 30% to the Union's electro-steel production, followed by Germany with 18.5% and Spain with 13.1% (FEDERACCIAI, several years). Currently, long products represent about 48.4% of steel production in Italy, flat products about 39.4%, and pipe the remaining 12.2%. Generally, the only integrated iron and steel plant is oriented towards flat production while, in steel plants equipped with electric ovens almost all located in the northern regions, long products are predominantly produced (e.g carbon steel, stainless steels) and seamless pipes (only one plant) (FEDERACCIAI, several years). Dioxins, PCB, HCB, PAH, Cd and Pb emissions are estimated on the basis of country specific emission factors at activity level, especially referring to sinter plants production, as provided by the main national operators. In particular, HCB emissions come from sinter plant productions and the emission factor is from the 2006 EMEP/CORINAIR Guidebook and it is coherent with data provided by the main national operator, at least for past years. The update of HMs and POPs emission factors with last available data started in the 2022 submission. On the basis of data collected in the framework of the IPPC permits, emission factors from point sources (sinter plants and blast furnaces) have been updated for As, Ni, Pb, Se, Cu, Hg, Zn, in the case of blast furnace it was also possible to estimate the PM10 emission factor. Again, on the basis of the IPPC data, the emission factors of NO_X, SO_X and PM10 from reheating furnaces have been estimated. Emission factors derived from this survey on the IPPC permits have been applied since 2016. As regards Cd emissions, these refer to blast furnaces, sinter and reheating activities; emission factors are those reported by the main Italian plant and emissions have been revised since 2003 based on the last review process and of E-PRTR data. For Hg and the other HMs emission factors are from the IPPC Bref sectoral report (JRC, 2013) and/or EMEP/EEA Guidebook 2006.

In the following Table 3.5 the main emission factors for the sector are reported. The data shown in the light blue cells are country specific based on emission data at plant level communicated in the framework of EPRTR, LCP, ETS or specific studies. Data reported in the dark blue cells represent country specific and fuel based emission factors. PM10 emission factors too, are country specific while PM2.5 factors have been derived from PM10 and the ratio PM2.5/PM10 per fuel as reported in the EMEP/EEA Guidebook 2019.

Table 3.5 Main emission factors 1A2 Iron and steel - 2023

	SO_x	NO_x	NMVOC	CO	Cd	Hg	Pb	PM2.5	PAH	Dioxins
	Kg/Mg product				g/Mg product					mg/Mg
Blast furnace cowpers										
areal sources	0.300	0.100	0.0003	0.189	0.001	0.026	0.100	9.938	-	-
point sources	0.190	0.092	0.0003	0.189	0.001	0.001	0.007	0.754	-	-
Sinter and pelletizing plants										
areal sources	0.515	0.859	0.090	16.105	0.023	0.020	3.700	54.593	0.025	0.0009
point sources	0.216	0.685	0.090	13.696	0.002	0.004	0.323	1.986	0.025	0.0001
Reheating furnaces steel and iron										
areal sources	0.036	0.103	0.010	0.050	0.017	0.016	0.117	5.444	-	-
point sources	0.040	0.116	0.005	0.272	0.017	0.016	0.117	0.329	-	-

3.3.1.2 Non-ferrous metals

1A2b, non-ferrous metal sector, includes emissions from grey iron foundries, lead, zinc, copper and secondary aluminium production. In particular, emission from the production of lead and zinc at the moment are entirely reported in the energy sector because up to now there was no information to distinguish between energy and process emissions and, above all, these processes are considered combustion processes with contact, consequently, emissions are dependent on the combustion process. In particular, in Italy no production of primary copper has ever occurred while, as regards lead and zinc, there is a sole integrated plant for the primary productions, and this makes it difficult to ensure a good breakdown. Consequently, the issue related to the allocation of emissions is not only about combustion and process but also about the different productions of different metals in the same factory. To resolve this issue, an in-depth investigation has been started with the aim to better specify the technology used on the basis of E-PRTR and IPPC permits. The first result of this investigation has been the update of certain EFs since 2014 (ISPRA, 2023 [b]; ISPRA, 2025 [c]).

HCB emission factors available in the Guidebook refer to the consumption of coal and other solid fuels and wood biomass while in Italy only natural gas and small amount of LPG and fuel oil are used so that HCB and PCB emissions from secondary aluminum production have been estimated and reported based on the information available in a national study. Dioxin emissions from this category are driven by emissions from secondary aluminum production where country specific emission factors are used from a research project of 2002 based on measurements at production plant level; such emissions are due prevalently to the role played by recycled material and there is no evidence of changes in the quality of the aluminum scraps as well as in the pretreatment process. Average emission factor is equal to 69 micrograms per Mg, and it is in the range of values of the Guidebook reported in the IPPU relevant sector but representing total emissions from this category. Dioxins emissions reported in 1A2b occur also for secondary production of lead, zinc and copper but in total their emissions are less than 10% of the total of 1A2b, one order of magnitude lower than those from aluminum production. An investigation is ongoing with the aim of reporting these emissions separately in the energy and IPPU sectors. Because emissions are up to now reported in the 1.A.2.b category, notation key IE has been provided for 2.C.3 category. For Hg emission factors are from EMEP/CORINAIR 2007 Guidebook. Moreover, up to 2013, for primary and secondary lead production, emission factors for SO_X, NO_X, NMVOC, CO, Pb, PM10 are country specific, from a sectoral technical survey (ENEA, 2000) and from the communication of the operators, as well as for PAH e dioxins (ENEA-AIB-MATTM, 2002). For the other pollutants emission factors are from EMEP/CORINAIR 2007 but they have been shared and checked with the main operator. For primary zinc production, up to 2013, SO_X, CO, Pb, PM, Zn and Cd emission factors are country specific as provided by the only operator while for the other pollutants are from the EMEP/CORINAIR Guidebook 2007 taking in account the weight of the different production processes, electrolytic and Imperial Smelting Furnace. Thanks to the investigation above mentioned emission factors for NO_x, SO_x, PM10, Pb, Cd e Zn from zinc and lead production have been updated on the basis of data at plant level (ISPRA, 2023 [b]; ISPRA, 2025 [c]). Over the years, the plant has undergone many transformations, with some modifications in particular impacting atmospheric emissions. Some of these modifications were: the Revamping of the Waelz plant, with the installation of the post-combustors on both Waelz lines, the new Solvent extraction plant (SX) and the revamping of the Kivcet plant, a new automatic big bags opening and unloading system for steelworks fumes, the reactivation of 3 chimneys of the plant, the insertion of the cruds and exhausted coals coming from the SX section, in the feed charge to the Waelz furnace. The latest plant modification, with a new environmental permit review application process, is in 2024 and involves the installation of a new oxide dryer at the Waelz plant.

For secondary aluminium production PAH and dioxins country specific emission factors have been used (ENEA-AIB-MATTM, 2002).

In the following Table 3.6 the main emission factors for the sector are reported. The data shown in the light blue cells are country specific based on emission data at plant level communicated in the framework of EPRTR, LCP, ETS or specific studies. PM10 emission factors too are country specific while PM2.5 emission factors have been derived from PM10 emission factors and the ratio PM2.5/PM10 per fuel as reported in the EMEP/EEA Guidebook 2019. The remaining emission factors derive from the EMEP/EEA Guidebook.

Table 3.6 Main emission factors 1A2 Non-Ferrous metals - 2023

	SO_x	NO_x	NMVOC	CO	Cd	Hg	Pb	PM2.5	PAH	Dioxins
	Kg/Mg product				g/Mg product					mg/Mg product
Grey iron foundries	0.125	0.160	0.090	9.500	0.140		7.200	423.529		
Primary lead production	0.050	0.009	0.000	0.000	0.045	3.000	9.681	1.443		
Primary zinc production	0.071	0.643		6.953	0.106	6.120	0.819	16.094		
Primary copper production										
Secondary lead production	0.722	0.066	0.000	0.000	0.000		31.173	2.942	0.006	0.005
Secondary zinc production	0.112	0.794	0.000	9.104	0.095	0.020	1.643	11.035		0.065
Secondary copper production		0.200	2.000		5.000		50.000	967.989		0.020
Secondary aluminium production	1.300	0.400	1.250					423.529	0.189	0.068
Other										
copper manufactures		0.200	2.000							
zinc-copper & brass manufactures		0.200	2.000							

3.3.1.3 Chemicals

Category 1A2c refers to the stationary combustion emissions from the chemical and petrochemical sectors. Emissions from this category are calculated on the basis of fuel consumption and the relevant emission factors and they are due to the auto production of energy and heat for the production processes. Natural gas and petrochemical gases are prevalently used in gas turbine plants. 1A2c is not level key category in 2023 for any pollutant,but is a key category at level assessment in 1990 for SOx. At a trend assessment, 1A2c is a key category for PM10, NOx and SOx. Emissions from the production processes are reported in the relevant IPPU sub sector. SO_X, NO_X and PM10 emission factors are country specific and derive from the communications of the main operators in the framework of the EPRTR and LCP framework while fuel consumption at plant level are provided in the ETS together with CO_2 emissions.

3.3.1.4 Pulp, paper and print

Category 1A2d refers to the stationary combustion emissions from the pulp and paper sector. Emissions from this category are calculated on the basis of fuel consumption and the relevant emission factors and they are due to the auto production of energy and heat for the production processes. Natural gas is prevalently used in gas turbine plants. It is not a key category at level and/or trend assessment for any pollutant. Emissions from the production processes are reported in the relevant IPPU sub sector. SO_X, NO_X and PM10 emission factors are country specific and derive from the communications of the main operators in the framework of the EPRTR and LCP framework while fuel consumption at plant level are provided in the ETS together with CO_2 emissions.

3.3.1.5 Food processing, beverages and tobacco

Category 1A2e refer to the stationary combustion emissions from the food and drink sector. Emissions from this category are calculated on the basis of fuel consumption and the relevant emission factors and they are due to the auto production of energy and heat for the production processes. Natural gas, and biogas are prevalently used in gas turbine plants. It is not a key category at level and/or trend assessment for any pollutant. Emissions from the production processes are reported in the relevant IPPU sub sector. SO_X, NO_X and PM10 emission factors are country specific and derive from the communications of the main operators in the framework of the EPRTR and LCP framework while fuel consumption at plant level are provided in the ETS together with CO_2 emissions.

3.3.1.6 Non-metallic minerals

Category 1A2f, stationary combustion in non-metallic mineral industry, refers to a multitude of production activities such as cement, lime, glass, brick and tiles, ceramics, and asphalt production which means a multitude of different emission factors. For cement production, PM emissions from kilns are reported in this category where emissions from mills are reported in IPPU (emission factor from USEPA 1991 emission factor handbook) while for lime production PM emission factors referring to the complete process are used (from USEPA 1996 emission factor handbook) and emissions are distributed between energy and IPPU. For Hg, emission factors are country specific (especially cement production which is the emission driver of this category); for Dioxin, HCB, PCB and Cd emission factors are from the relevant Bref reports or EMEP/EEA 2007 Guidebook; for Pb, emission factors are country specific for ceramic production and from the Bref report or EMEP 2006 Guidebook for glass, cement and lime productions.

In the following Table 3.7 the main emission factors for the sector are reported. The data shown in the light blue cells are country specific based on emission data at plant level communicated in the framework of EPRTR, LCP, ETS or specific studies. PM10 emission factors too are country specific while PM2.5 emission factors have been derived from PM10 emission factors and the ratio PM2.5/PM10 per fuel as reported in the EMEP/EEA Guidebook 2019. The remaining emission factors derive from the EMEP/EEA Guidebook.

Table 3.7 Main emission factors 1A2 Non-Metallic minerals - 2023

	SO_x	NO_x	NMVOC	CO	Cd	Hg	Pb	PM2.5	PAH	Dioxins
	Kg/Mg product				g/Mg product					mg/Mg product
Plaster furnaces	0.115	0.088	0.009	0.013				0.990		
Cement	0.387	0.798	0.023	1.072	0.008	0.030	0.006	2.127		0.0001
Lime										
areal sources	0.064	0.972	0.004	0.013		0.001		0.800		
point sources	0.018	0.077	0.004	0.013		0.001		0.800		
Asphalt concrete plants	0.002	0.011	0.004	0.002				6.500	0.0004	
Flat glass	0.938	1.846	0.044	0.100			0.330	350.000		
Container glass	0.923	1.218	0.047	0.100	0.090		4.550	448.800		
Glass wool (except binding)	2.500	1.014	0.048	0.081				123.390		
Other glass		2.690	0.100	0.260			10.000	17.778		
Mineral wool (except binding)	1.500			3.200				493.559		
Bricks and tiles	0.785	0.250	0.007	0.040				49.841		

	SO_x	NO_x	NMVOC	CO	Cd	Hg	Pb	PM2.5	PAH	Dioxins
	Kg/Mg product				g/Mg product					mg/Mg product
Fine ceramic materials	0.569	0.174	0.014	0.130			6.000	193.898		

3.3.1.7 Other

Category 1A2g refers to the stationary combustion emissions from different industrial sectors such as machinery, mining and quarrying, construction, textile and others. Emissions from this category are calculated on the basis of fuel consumption and the relevant emission factors and they are due to the auto production of energy and heat for the production processes. Natural gas is prevalently used in gas turbine plants. Emissions from off-roads vehicles used in industry are also reported under this category. Fugitive emissions from the oil and gas extraction activities are reported in the relevant energy sub sector. SO_X, NO_X and PM10 emission factors are country specific and derive from the communications of the main operators in the framework of the EPRTR and LCP framework while fuel consumption at plant level are provided in the ETS together with CO_2 emissions.

3.3.2 Time series and key categories

In 2023, manufacturing industries and construction (1A2) is a main source of heavy metals and POPs, accounting for about 55.7% of HCB total emissions, 35.4% for lead, 32.6% for SOx, 27.7% for cadmium, 21.8% for Hg and 19.3% for dioxin. The sector is key category also for PM10 and PM2.5 (3.5% and 4.2% respectively) as well as NO_x and CO, about 7.7% and 4.6% of total emissions. In 2023 the main sectors are Stationary combustion in iron and steel industries (1A2a), which is key for Cd, and Hg, Stationary combustion in non-ferrous metal industries (1A2b), key for Dioxin and HCB, and stationary combustion in non-metallic mineral industries (1A2f) that is key category for SO_X, NO_X, PM10, PM2.5, Pb, Cd and Hg.

As already reported for 1A1 category, a strong reduction of SO_X, NO_X and PM10 emissions is observed for this category along the time series. The introduction of two regulatory instruments: the DPR 203/88 (Decree of President of the Republic of 24th May 1988), laying down rules concerning the authorization of plants, and the Ministerial Decree of 12th July 1990, which introduced plant level limits to emissions of PM10, NO_X and SO_X for new plants and required old plants to conform to the limit by 1997, explained the emission reduction in the nineties. The shift from fuel oil to natural gas combined with the increase of energy efficiency of the plants and the introduction of PM10 abatement technologies have been implemented to comply with the emission limit values. From 2000 lower limits to emissions at the stacks have been introduced, in the framework of environmental integrated authorizations, for the authorization of new plants and the implementation of the old ones, especially for those facilities located in areas with air quality critical values. For this reason, the plants have increased the use of natural gas heat and power combined technology.

3.3.2.1 Iron and steel

The category 1A2a in 2023 is a key category for Cd and Hg. The trend of emissions is linked above all to the production levels and then to the abatement technologies.

In fact, for the majority of pollutants, in 2009 a strong reduction of emissions is observed due to the effects of the economic recession that in 2010 and 2011 has partially recovered. In 2012 a further drop occurred for the economic crisis and for environmental constraints of the main iron and steel integrated plants that should reduce their productions. In 2015 a drop is still observed consistently with the production activities reduction of the main iron and steel integrated plants. There were four integrated steel plants in 1990 that from 2005 are reduced to two, with another plant that still has a limited production of pig iron. Nevertheless, the steel production in integrated plants has not changed significantly in the 1990-2008 period due to an expansion in capacity of the two operating plants. From 2015 only one integrated plant remains in operation. The maximum production was around 11 Mt/y in 1995 and in 2005-2008, with lower values in other years and the lowest of 3.0 Mt in 2023.

3.3.2.2 *Non-ferrous metals*

The category 1A2b in 2023 is a key category for dioxins and HCB.

In Italy, the production of primary aluminium stopped in 2013 (and was 232 Gg in 1990) while secondary aluminium accounts for 350 Gg in 1990 and 715 Gg in 2023. These productions, however, use electricity as the primary energy source so the emissions due to the direct use of fossil fuels are limited. The sub sector comprises also the production of other non-ferrous metals, both primary and secondary copper, lead, zinc and others; as above reported, point data by plant authorization for the sole integrated Zn/Pb plant led to more accurate EFs for NO_X, SO_X, CO, PM, Cd, Pb and Zn and, as a consequence, some limited recalculations. The operation of the plant in 2023 was characterised by a reduced run due to the energy crisis in the European market, against which a strategic shutdown was planned, in particular for the Kivcet and Zinc line. For this reason, the emissions for the year 2023 are generally lower than in previous years and come almost entirely from the Waelz plant. Detailed information on the integrated plant, of its transformations and emissions are reported in the ISPRA Technical note (ISPRA, 2023 [b]; ISPRA, 2025 [c]).

3.3.2.3 *Chemicals*

In Italy there are petrochemical plants integrated with a nearby refinery and stand-alone plants that get the inputs from the market. Main products are Ethylene, Propylene, Styrene. In particular, ethylene and propylene are produced in petrochemical industry by steam cracking. Ethylene is used to manufacture ethylene oxide, styrene monomer and polyethylene. Propylene is used to manufacture polypropylene but also acetone and phenol. Styrene, also known as vinyl benzene, is produced on an industrial scale by catalytic dehydrogenation of ethyl benzene. Styrene is used in the rubber and plastic industry to manufacture through polymerisation processes such products as polystyrene, ABS, SBR rubber, SBR latex. Except for ethylene oxide, whose production has stopped in 2002, the other productions of the above-mentioned chemicals still occur in Italy. Activity data are stable from 1990 to 2012, with limited yearly variations along the time series and a reduction in the last years. Chemical industry includes non-organic chemicals such as chlorine/soda, sulphuric acid, nitric acid, ammonia. A limited production of fertilizers is also present in Italy. From 1990 to 2023, most productions are in sharp decline (-100% for dichloroethane, vinylchoride, polyvinylchloride, acrylonitrile, -98% for ammonium sulphate, 90% NPK fertilizers, -79% ammonia, -69% nitric acid, -57 for sulfuric acid) with the exception of very few activities such as adipic acid with +16%.

3.3.2.4 *Pulp, paper and print*

Emissions from the manufacturing of paper are included in this source category. In Italy the manufacture of virgin paper pulp is rather limited, with a production feeding less than 5% of the produced paper. Most of the pulp was imported in 1990, while in 2023 half of the pulp used is produced locally from recycled paper. The paper production is expanding, and activity data (total paper produced) were 6.2 Mt in 1990 and 7.5 Mt in 2023. The printing industry represents a minor part of the source category emissions.

3.3.2.5 *Food processing, beverages and tobacco*

In Italy the food production industry is expanding. A comprehensive activity data for this sector is not available; more in detail while energy data are those reported in the national energy balance for this sector, information at subsector and technological level is not available and only few plants are part of the ETS; energy fuel consumption was estimated to be 62 PJ in 1990 and 106 PJ in 2023, about half of energy consumptions derives from biomass (99.5% biogas).

3.3.2.6 *Non-metallic minerals*

The category 1A2f in 2023 is a key category for SO_X (27.5%), NO_X (5.1%), PM10 (2.4%), PM2.5 (3.0%), Pb (29.7%), Cd (13.4%) and Hg (10.7%). This sector, which refers to construction materials, is quite significant in terms of emissions due to the energy intensity of the processes involved. Construction materials subsector includes the production of cement, lime, bricks, tiles and glass. It comprises thousands of small and medium size enterprises, with only few large operators, mainly connected to cement production. Some of the production is also exported.

3.3.2.7 *Other*

This sector comprises emissions from many different industrial subsectors, some of which are quite significant in Italy in terms of both added value and export capacity. In particular, engineering sector (vehicles and machines manufacturing) is the main industrial sub sector in terms of added value and revenues from export and textiles was the second subsector up to year 2000. The remaining "other industries" include furniture and other various "made in Italy" products that produce not negligible amounts of emissions.

3.3.3 QA/QC and verification

As already reported, QA/QC checks at plants level are directed to check the submissions of data in the different context and evaluate the differences if any. For example, if emissions submitted by a plant under LCP are higher than those submitted under the EPRTR, ISPRA asks the operator of the reporting plant for an explanation and the verification of data submitted. In addition, on the basis of fuel consumption supplied under the ETS and average emission factor by fuel energy, experts estimate emissions at plant level and compare them with those submitted in the EPRTR and LCP. Also, in this case ISPRA asks for clarifications to the reporting plant if necessary. As for 1A1 point sources, the analysis of data collected from point sources allowed to distribute emissions at local level and to check and verify data at local level.

3.3.4 Recalculations

For 1.A.2 category some recalculations occurred in this submission.

In general, recalculations in 2022 are due to the update of activity data reported in the National Energy Balance or in production activity data.

Recalculations greater than 1% occurred in 2022 for NO_X (-7.8%) and NH_3 (-14.1%) because of the update of the relevant emission factors from cement production; for PM10 (+1.0%) because of the update of lime production activity data; for Hg (-1.1%) and Pb (+2.6%) because of the update of the emission factor from lead and zinc production.

As regards lead and zinc production in Italy there is a sole integrated plant for the primary productions and the consultation of environmental permits and data declared in the EPRTR framework led to a gap filling operation and therefore to minor recalculations for the years 2014-2018 and 2020-2022.

3.3.5 Planned improvements

Specific improvements are detailed in the 2025 QA/QC plan (ISPRA, 2025[b]).

Following the update of lead and zinc production the reconstruction of the time series ante 2014 is planned to ensure consistency.

For the energy sector, a major progress regards the management of the information system where data collected in the framework of different obligations, Large Combustion Plant, E-PRTR and Emissions Trading, are gathered together thus highlighting the main discrepancies in information and detecting potential errors. Moreover, the complete use of the energy data provided by the Ministry of Environment to the Joint Questionnaire IEA/OECD/EUROSTAT is planned in substitution of the national energy balances used till now; liquid, gaseous and solid fuel are now aligned for the whole time series and renewable fuels and biomass too have been used as possible.

3.4 AVIATION (NFR SUBSECTOR 1.A.3.A)

3.4.1 Overview

Emissions from categories 1.A.3.a.i International Aviation and 1.A.3.a.ii Domestic Aviation are estimated, including figures both for landing and take-off cycles (LTO) and for the cruise phase of the flight (the latter reported as memo items and not included in the national totals).

3.4.2 Methodological issues

According to the IPCC Guidelines and Good Practice Guidance (IPCC, 1997; IPCC, 2006; IPCC, 2000) and the EMEP/EEA Guidebook 2023 (EMEP/EEA, 2023), a national technique has been developed and applied to estimate emissions. The current method estimates emissions from the following assumptions and information. Activity data comprise both fuel consumptions and aircraft movements, which are available in different level of aggregation and derive from different sources as specified here below:

- Total inland deliveries of aviation gasoline and jet fuel are provided in the national energy balance (MASE, several years (a)). This figure is the best approximation of aviation fuel consumption, for international and domestic use, but it is reported as a total and not split between domestic and international.
- Data on annual arrivals and departures of domestic and international landing and take-off cycles at Italian airports are reported by different sources: National Institute of Statistics in the statistics yearbooks (ISTAT, several years), Ministry of Transport in the national transport statistics yearbooks (MIMS, several years), the Italian civil aviation in the national aviation statistics yearbooks (ENAC/MIMS, several years), EUROCONTROL flights data time series 2002–2023 (EUROCONTROL, several years).

An overall assessment and comparison with EUROCONTROL emission estimates was carried out over the years and that lead to an update of the methodology used by Italy for this category. Data on the number of flights, fuel consumption and emission factors were provided by EUROCONTROL in the framework of a specific project funded by the European Commission, and quality checked by the European Environmental Agency and its relevant Topic Centre (ETC/ACM), aimed at improving the reporting and the quality of emission estimates from the aviation sector of each EU Member State under both the UNFCCC and LRTAP conventions. The Advanced Emissions Model (AEM) was applied by EUROCONTROL to derive these figures, according to a Tier 3 methodology (EMEP/EEA, 2023). EUROCONTROL fuel and emissions time series cover the period 2005-2023, while the number of flights is available since 2002. For the time series from 1990 to 1999, figures for emission and consumption factors are derived by the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007), both for LTO cycles and cruise phases, taking into account national specificities.

These specificities derived from the results of a national study which, taking into account detailed information on the Italian air fleet and the origin-destination flights for the year 1999, calculated national values for both domestic and international flights (Romano et al., 1999; ANPA, 2001; Trozzi et al., 2002 (a)) on the basis of the default emission and consumption factors reported in the EMEP/CORINAIR guidebook. National average emissions and consumption factors were therefore estimated for LTO cycles and cruise both for domestic and international flights from 1990 to 1999. Specifically, for the year referred to in the survey, the method estimates emissions from the number of aircraft movements broken down by aircraft and engine type (derived from ICAO database if not specified) at each of the principal Italian airports; information about whether the flight is international or domestic and the related distance travelled has also been considered. A Tier 3 method has been applied for 1999. In fact, figures on the number of flights, destination, aircraft fleet and engines have been provided by the local airport authorities, national airlines and EUROCONTROL, covering about 80% of the national official statistics on aircraft movements for the relevant years. Data on 'Times in mode' have also been supplied by the four principal airports and estimates for the other minor airports have been carried out on the basis of previous sectoral studies at local level. Consumption and emission factors are those derived from the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007). Based on sample information, estimates have been carried out at national level from 1990 to 1999 considering the official statistics of the aviation sector (ENAC/MIMS, several years) and applying the average consumption and emission factors.

From 2005, fuel consumption and emission factors were derived from the database made available to EU Member States by EUROCONTROL, as previously described. These data were used for updating fuel consumption factors, and emission factors of all pollutants. For the period between 1999 and 2005, interpolation has been applied to calculate these parameters. Estimates were carried out applying the consumption and emission factors to the national official aviation statistics (ENAC/MIMS, several years) and EUROCONTROL data on movements from 2002 (EUROCONTROL, several years). In general, to carry out national estimates of greenhouse gases and other pollutants for LTO cycles, both domestic and international, consumptions and emissions are calculated for the complete time series using the average consumption and emission factors multiplied by the total number of flights. The same method is used to estimate emissions for domestic cruise; on the other hand, for international cruise, consumption is derived by difference from the total fuel consumption reported in the national energy balance and the estimated values as described above and emissions are therefore calculated.

Data on domestic and international aircraft movements from 1990 to 2023 are shown in Table 3.8 where domestic flights are those entirely within Italy. Since 2002, EUROCONTROL flights data have been considered, accounting for departures from and arrivals to all airports in Italy, regarding flights flying under instrument flight rules (IFR), including civil helicopters flights and excluding flights flagged as military, when the above flights can be identified. Total fuel consumption, both domestic and international, is reported by LTO and cruise in Table 3.9.

Table 3.8 Aircraft Movement Data (LTO cycles)

Number of flights	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Domestic flights	172,148	185,220	319,748	350,140	354,520	280,645	151,156	209,721	286,496	286,194
International flights	147,875	198,848	303,608	381,206	406,990	425,410	172,835	232,750	419,862	485,543

Source: ISTAT, several years; ENAC/MIMS, several years; Eurocontrol, several years.

Table 3.9 Aviation jet fuel consumptions for domestic and international flights (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
Domestic LTO	111	120	208	233	227	168	89	123	176	173
International LTO	130	175	258	269	296	328	130	162	301	361
Domestic cruise	357	384	654	666	704	526	291	421	620	584
International cruise	1,246	1,688	2,297	2,456	2,534	2,745	1,087	1,432	2,625	3,366

Source: ISPRA elaborations

Emissions from military aircrafts are also estimated and reported under category 1.A.5 Other. The methodology to estimate military aviation emissions is simpler than the one described for civil aviation since LTO data are not available in this case. As for activity data, total consumption for military aviation is published in the petrochemical bulletin (MASE, several years (b)) by fuel. Emission factors are those provided in the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007). Therefore, emissions are calculated by multiplying military fuel consumption data for the EMEP/CORINAIR default emission factors.

3.4.3 Time series and key categories

Emission time series of NO_X, NMVOC, SO_X, TSP, CO, Pb are reported in Table 3.10, Table 3.11, Table 3.12, Table 3.13, Table 3.14 and Table 3.15, respectively.

An upward trend in emission levels for civil aviation is observed from 1990 to 2019, which is explained by the increasing number of LTO cycles. Nevertheless, the propagation of more modern aircrafts in the fleet slows down the trend in the most recent years. There has also been a decrease in the number of domestic flights from 2000, although a new increasing trend in the last couple of years has been registered. Year 2020 is to be considered separately, because the aviation sector was severely hit by the pandemic measures: domestic flights in 2020 were about the 52% of the 2019, while international flights during 2020 were the 34% of the flights of the previous year. In 2023 the number of domestic flights has no significant variations, while international flights have increased by 16% in comparison with the year 2022. Aviation is not a key category.

Table 3.10 Time series of NO_X (Gg)

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
1 A 3 a ii (i) Domestic aviation LTO (civil)	1.36	1.47	2.50	2.55	2.71	2.12	1.15	1.59	2.36	2.28
1 A 3 a i (i) International aviation LTO (civil)	1.60	2.16	3.20	3.47	3.99	4.55	1.85	2.33	4.32	5.22
1 A 3 a Civil Aviation (LTO)	**2.97**	**3.62**	**5.70**	**6.02**	**6.70**	**6.68**	**3.01**	**3.92**	**6.68**	**7.50**
1A3 a ii (ii) Domestic aviation cruise (civil)	5.23	5.63	9.43	8.71	10.16	8.09	4.25	5.68	8.55	8.54
1A3a i (ii) International aviation cruise (civil)	18.85	26.83	38.99	36.55	41.02	47.05	18.56	19.05	34.51	44.96
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**11.16**	**11.99**	**7.24**	**13.50**	**6.11**	**3.29**	**3.48**	**1.94**	**2.79**	**1.95**

Table 3.11 Time series of NMVOC (Gg)

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.12	0.13	0.23	0.25	0.33	0.27	0.14	0.18	0.25	0.23
1 A 3 a i (i) International aviation LTO (civil)	0.15	0.20	0.31	0.39	0.45	0.48	0.16	0.20	0.36	0.40
1 A 3 a Civil Aviation (LTO)	**0.27**	**0.33**	**0.54**	**0.64**	**0.78**	**0.75**	**0.31**	**0.39**	**0.61**	**0.63**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.10	0.10	0.18	0.20	0.37	0.34	0.19	0.26	0.34	0.34
1A3a i (ii) International aviation cruise (civil)	0.25	0.36	0.55	0.69	0.81	0.89	0.29	0.37	0.69	0.77
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**3.00**	**3.13**	**1.90**	**3.00**	**1.05**	**0.66**	**0.77**	**0.41**	**0.62**	**0.44**

Table 3.12 Time series of SO_X (Gg)

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.11	0.12	0.21	0.23	0.23	0.17	0.09	0.12	0.18	0.17
1 A 3 a i (i) International aviation LTO (civil)	0.13	0.17	0.26	0.27	0.30	0.33	0.13	0.16	0.30	0.36
1 A 3 a Civil Aviation (LTO)	**0.24**	**0.29**	**0.47**	**0.50**	**0.52**	**0.50**	**0.22**	**0.28**	**0.48**	**0.53**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.36	0.38	0.65	0.67	0.70	0.53	0.29	0.42	0.62	0.62
1A3a i (ii) International aviation cruise (civil)	1.25	1.78	2.60	2.45	2.65	2.95	1.16	1.36	2.45	3.14
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**1.19**	**0.81**	**0.21**	**0.17**	**0.13**	**0.12**	**0.19**	**0.09**	**0.16**	**0.11**

Table 3.13 Time series of TSP (Gg)

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.01	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.02
1 A 3 a i (i) International aviation LTO (civil)	0.02	0.03	0.04	0.05	0.03	0.04	0.01	0.02	0.03	0.04
1 A 3 a Civil Aviation (LTO)	**0.03**	**0.04**	**0.06**	**0.07**	**0.06**	**0.05**	**0.02**	**0.03**	**0.05**	**0.06**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.07	0.08	0.13	0.10	0.10	0.07	0.04	0.06	0.09	0.08
1A3a i (ii) International aviation cruise (civil)	0.36	0.52	0.75	0.71	0.83	0.91	0.30	0.37	0.71	0.79
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**1.30**	**1.57**	**0.91**	**1.63**	**0.83**	**0.48**	**0.56**	**0.30**	**0.46**	**0.32**

Table 3.14 Time series of CO (Gg)

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
1 A 3 a ii (i) Domestic aviation LTO (civil)	1.23	1.33	2.26	2.33	2.28	1.69	0.94	1.24	1.73	1.67

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Gg				
1 A 3 a i (i) International aviation LTO (civil)	1.73	2.32	3.33	2.86	3.00	3.25	1.25	1.48	2.73	3.28
1 A 3 a Civil Aviation (LTO)	**2.96**	**3.64**	**5.59**	**5.19**	**5.28**	**4.94**	**2.19**	**2.72**	**4.46**	**4.95**
1A3 a ii (ii) Domestic aviation cruise (civil)	1.31	1.41	2.43	2.66	3.07	2.35	1.47	2.18	2.83	2.82
1A3a i (ii) International aviation cruise (civil)	2.03	2.89	4.42	5.55	5.74	6.07	2.49	3.65	6.47	7.62
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**65.12**	**79.02**	**45.49**	**54.48**	**17.33**	**16.49**	**24.93**	**11.98**	**20.34**	**14.60**

Table 3.15 Time series of Pb (Mg)

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						Mg				
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.19	0.20	0.35	0.38	0.38	0.30	0.16	0.23	0.31	0.31
1 A 3 a i (i) International aviation LTO (civil)	0.21	0.28	0.43	0.54	0.57	0.60	0.24	0.33	0.59	0.68
1 A 3 a Civil Aviation (LTO)	**0.39**	**0.48**	**0.77**	**0.91**	**0.96**	**0.90**	**0.41**	**0.55**	**0.90**	**0.99**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.57	0.62	1.06	1.16	1.18	0.93	0.50	0.70	0.95	0.95
1A3a i (ii) International aviation cruise (civil)	2.01	2.86	4.36	5.48	5.85	6.11	2.48	3.34	6.03	6.98
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**16.34**	**4.22**	**1.16**	**0.001**	**NA**	**0.12**	**0.18**	**0.10**	**0.09**	**0.002**

3.4.4 QA/QC and Uncertainty

Data used for estimating emissions from the aviation sector derive from different sources: local airport authorities, national airlines operators, EUROCONTROL and official statistics by different Ministries and national authorities.

Different QA/QC and verification activities are carried out for this category. As regards past years, the results of the national studies and methodologies, applied at national and airport level, were shared with national experts in the framework of an ad hoc working group on air emissions instituted by the National Aviation Authority (ENAC). The group, chaired by ISPRA, included participants from ENAC, Ministry of Environment, Land and Sea, Ministry of Transport, national airlines and local airport authorities. The results reflected differences between airports, aircrafts used and times in mode spent for each operation.

Currently, verification and comparison activities regard activity data and emission factors. In particular, number of flights has been compared considering different sources: ENAC, ASSAEROPORTI, ISTAT, EUROCONTROL and verification activities have been performed on the basis of the updated EUROCONTROL data on fuel consumption and emission factors resulting in an update and improving of the national inventory. Furthermore, there is an ongoing collaboration and data exchange with regional environmental agencies on this issue.

3.4.5 Recalculations

No recalculations have been made in this submission.

3.4.6 Planned improvements

Improvements for the next submissions are planned on the basis of the outcome of the ongoing quality assurance and quality control activities, in particular with regard to the results of investigation about data and information deriving from different sources, in particular further assessment of EUROCONTROL data, and comparison with information provided by the national institute of statistics, ISTAT, on the number of flights.

3.5 ROAD TRANSPORT (NFR SUBSECTOR 1.A.3.B)

3.5.1 Overview

The road transport sector contributes to the total national emissions in 2023 as follows: nitrogen oxides emissions for 40.2% of the total, emissions of carbon monoxide for 14.9%, non-methane volatile organic compounds for 10.4%, PM10 and PM2.5, for 9.8% and 8.9%, respectively, of the total.

The estimation refers to the following vehicle categories:

- 1.A.3.b.i Passenger cars
- 1.A.3.b.ii Light-duty trucks
- 1.A.3.b.iii Heavy-duty vehicles including buses
- 1.A.3.b.iv Mopeds and motorcycles
- 1.A.3.b.v Gasoline evaporation
- 1.A.3.b.vi Road transport: Automobile tyre and brake wear
- 1.A.3.b.vii Road transport: Automobile road abrasion

3.5.2 Methodological issues

A national methodology has been developed and applied to estimate emissions according to the IPCC Guidelines and Good Practice Guidance (IPCC, 1997; IPCC, 2000; IPCC, 2006) and the EMEP/EEA Guidebook (EMEP/EEA, 2023).

In general, the annual update of the model is based on the availability of new measurements and studies regarding road transport emissions (for further information see: https://www.emisia.com/utilities/copert/). The model COPERT 5 (updated version 5.8.1, September 2024) has been used and applied for the whole time series in 2024 submission. COPERT 5 introduced over the years upgrades both from software and methodological point of view (https://www.emisia.com/utilities/copert/versions/). Several new methodological features had been introduced respect to the previous model COPERT 4. As regards fuel, updates concerned: fuel energy instead of fuel mass calculations; distinction between primary and end (blends) fuels, automated energy balance. Regarding vehicle types, updated vehicle category naming, new vehicle types and emission control technology level, have been introduced. As regards emission factors, one function type and the possibility to distinguish between peak/off-peak urban, have been implemented.

Main methodological innovations introduced in version 5.8.1 respect to version 5.7.3 , used in last submission, relate: the introduction of Euro 7 vehicles; the introduction of Euro VI CNG & LNG HDVs; the revision of CO, EC, SPN23, NOx of Euro 6 HEV/PHEV; the revision of VOCs speciation of Euro 5/6 petrol & diesel LDVs; the revision of EC of BEVs; the revision of cold PM & BC of Euro 5/6 petrol, diesel & CNG LDVs; the revision of EC of Euro 6 LPG cars; the revision of Euro 5 motorcycles.
As regards the software, revisions relate: the extension of the functionalities of the Command Line Interface regarding ability to point to an existing .cop file, all pollutants, mileage degradation; the Energy Consumption from A/C for battery electric cars.
In addition, the following bugs have been solved: share of cold CH4 and NMVOC over VOC for Euro 6 LDVs; hot CH_4 emission factors of LPG cars; PM, PN emission factor of CNG/LPG Euro 5 & 6 vehicles; minor issues.

Respect to last submission, the following vehicle categories have been introduced: Battery electric Light Commercial Vehicles, CNG and LNG Heavy Duty Trucks, Battery electric Buses.

The model, on the basis of the inputs inserted, gives output results separately for vehicles category and urban (peak/off-peak urban), rural, highway areas, concerning emission estimates of CO, VOC, NMVOC, CH_4, NO_X, N_2O, NH_3, PM2.5, PM10, PM exhaust (the emission factors of particulate matter from combustion refer to particles smaller than 2.5 µm, that implicitly assumes that the fraction of particulate matter with diameter between 2.5 µm and 10 µm is negligible), CO_2, SO_2, heavy metals, NO_X speciation in NO e NO_2, the speciation in elemental and organic carbon of PM, the speciation of NMVOC. Resulting national emission factors at detailed level are available on the following public web address: https://fetransp.isprambiente.it/#/. Data on fuel consumption of gasoline, diesel, liquefied petroleum gas (LPG), natural gas (CNG) and biofuels are those reported in the EUROSTAT energy balance; Italian road vehicles electricity consumption data, introduced recently in COPERT in relation to the evolution of the fleet, derive from Eurostat database (https://ec.europa.eu/eurostat/data/database). Time series of consumptions, by fuel and vehicle categories, are detailed in the NFR. Lubricants consumption is estimated and reported in 1A3b.

3.5.2.1 Exhaust emissions

Exhaust emissions from vehicles subsectors are split between cold and hot emissions; estimates are calculated either on the basis of a combination of total fuel consumption and fuel properties data or on the basis of a combination of drive related emission factors and road traffic data.

The calculation of emissions is based on emission factors calculated for the vehicle models most widely and systematically used, distinguishing between the type of vehicle, fuel, engine size or weight class, standard legislation. The legislative standards introduced become more stringent over the years, ensuring that new vehicles emit much less than the older ones as regards the regulated pollutants. With reference to four groups of pollutants, the method of calculation of exhaust emissions is different. The methodology implemented is derived from the EMEP/EEA Emission Inventory Guidebook 2023 (EMEP/EEA, 2023). As regards the first two groups, methods are used leading to high standard detailed emissions data.

The first group includes: CO, NO_X, VOC, CH_4, NMVOC, N_2O, NH_3 and PM. For these pollutants, specific emission factors are applied relating to different engine conditions and urban, rural and highway driving shares.

The second group includes: CO_2, SO_2, Pb, Cd, Cr, Cu, Ni, Se, Zn. The emissions of these pollutants are estimated on the basis of fuel consumption.

For the third group of pollutants, including PAHs and PCDDs and PCDFs, detailed data are not available and then a simplified methodology is applied.

Finally, the fourth group includes pollutants (alkanes, alkenes, alkynes, aldehydes, ketones, cycloalkanes and aromatic compounds) obtained as a fraction of the total emissions of NMVOC, assuming that the fraction of residual NMVOC are PAHs.

Because of the availability in Italy of an extensive and accurate database, a detailed methodology is implemented in the model COPERT 5. Total emissions are calculated as the sum of hot emissions, deriving from the engine when it reaches a hot temperature, and cold emissions produced during the heating process. The different methodological approach is justified by the performance of vehicles in the two different phases. The production of emissions is also closely linked to the driving mode, differentiating for activity data and emission factors, with reference to urban (where it is assumed that almost all cold emissions are produced), rural and highway shares. Several factors contribute to the production of hot emissions such as mileage, speed, type of road, vehicle age, engine capacity and weight. Cold emissions are mainly attributed to urban share, and are attributed only to passenger cars and light duty vehicles. Varying according to the weather conditions and driving behaviour, are related to the specific country.

Emissions of NMVOC, NO_X, CO and PM are calculated on the basis of emission factors expressed in grams per kilometre and road traffic statistics estimated by ISPRA on account of data released from Ministry of Transport, ACI and ANCMA (several years). The emission factors are based on experimental measurements of emissions from in-service vehicles of different types driven under test cycles with different average speeds calculated from the emission functions and speed-coefficients provided by COPERT 5 (EMISIA SA, 2024). This source provides emission functions and coefficients relating emission factors (in g/km) to average speed for each vehicle type and Euro emission standard derived by fitting experimental measurements to polynomial functions. These functions were then used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of road and area types. As regards the speciation of PM into elemental (EC, assumed to be equal to black carbon for road transport) and organic carbon (OC), considering the organic material (OM) as the mass of organic carbon corrected for the hydrogen content of the compounds collected, since the estimates are based on the assumption that low-sulphur fuels are used, when advanced after treatments are used, EC and OM do not add up to 100%, assuming that the remaining fraction consists of ash, nitrates, sulphates, water and ammonium salts (EMEP/EEA 2023).

Emissions of fuel dependent pollutants have been estimated applying a different approach. Data on consumption of various fuels are derived from official statistics aggregated at national level and then estimated in the detail of vehicle categories, emission regulation and road type in Italy. The resulting error of approximation deriving from the comparison between the calculated value and the statistical value of the total fuel consumption, is corrected by applying a normalisation procedure to the breakdown of fuel consumption by each vehicle type calculated on the basis of the fuel consumption factors added up, with reference to the BEN figures for total fuel consumption in Italy (adjusted for off-road consumption). The 1990-2023 inventory uses fuel consumption factors expressed as MJ per kilometre for each vehicle type and average speed calculated from the emission functions and speed-coefficients provided by the model COPERT 5, version 5.8.1. Emissions of sulphur dioxide and heavy metals are calculated applying specific factors to consumption of gasoline, diesel, liquefied petroleum gas (LPG) and natural gas (CNG), taken from the BEN (MASE, several years (a)), updated since 2017 according to EUROSTAT methodology.

Emissions of SO_2 are based on the sulphur content of the fuel. Values for SO_2 vary annually as the sulphur-content of fuels change and are calculated every year for gasoline and gas oil and officially communicated to the European Commission in the framework of the European Directives on fuel quality; these figures are also published by the refineries industrial association (UNEM, several years). Fuel specifications for gasoline, diesel fuel and LPG, derive from ad hoc studies about the properties of transportation fuels sold in Italy and whose results are representative and applicable with reference to three different time phases: 1990 – 1999; 2000 – 2012; 2013 – 2019; since 2020 (Innovhub – Fuel Experimental Station surveys, several years). In particular the results obtained for biodiesel in 2020 have been used to update the entire fuel specifications historical series (previously, in the absence of country specific parameters, Eurostat Energy Balance parameters were used).

As regards natural gas, the national market is characterized by the commercialisation of gases with different chemical composition in variable quantities from one year to the other. Each year the quantities of natural gas imported or produced in Italy are published on the web: https://sisen.mase.gov.it/dgsaie/ (Ministry of Environment, Ministry of Industry, several years).

In Italy, biodiesel, biogasoline and biogas are used in road transportation and the respective emissions have been estimated in the Inventory. As regards biodiesel and biogasoline, over the years almost all the commercial gasoline is practically still substantially an E0 (but in 2023 biogasoline consumption has more than doubled respect to 2022 and the share is about 1%, respect to the total road gasoline consumption), while the distributed diesel reaches up to 5-7% by volume of biodiesel in diesel fuel (in 2023 the share of biodiesel is 5.4%, respect to the total road diesel consumption). That is because Italian producers/refineries have decided since the beginning of the introduction of the obligations on biofuels to focus on biodiesel rather than on ethanol to comply with the European/Italian obligations to introduce bio-fuels on the market. Biogasoline represents to date a minimum percentage out of the total gasoline including biogasoline consumption. According to the Renewable energy Directive (2009/28/EC) the amount of biogasoline reported in the Energy balance is equal to the renewable part of the fuel, calculated as the 37% of the total volume placed on the market. Biodiesel has been tested since 1994 to 1996 before entering in production since 1998. Moreover biogas road consumption is taken into account in the Inventory, representing about 32.8% of total road natural gas consumption in 2023. It is reported since year 2020 in the IEA - Eurostat – UNECE Energy Questionnaire (as element not covered by Regulation EC No 1099/2008 on energy statistics, therefore it is not mandatory for Countries to transmit it to Eurostat).

Emissions of heavy metals are estimated on the basis of data regarding the fuel and lubricant content and the engine wear; as reported in the EMEP/EEA Emission Inventory Guidebook 2023, these apparent fuel metal content factors originate from the work of Winther and Slentø, 2010, and have been reviewed by the TFEIP expert panel in transport and because of the scarce available information, the uncertainty in the estimate of these values is still considered quite high. In COPERT model heavy metals emission factors have been then updated focusing on the distinction between exhaust and non exhaust share. Non exhaust emissions of PAHs have also been estimated on the basis of brake and tyres debris-bound values resulting from the EMEP/EEA guidebook 2023.

3.5.2.2 *Evaporative emissions*

As regards NMVOC, the share of evaporative emissions is provided. These emissions are calculated only for gasoline vehicles: passenger cars, light duty vehicles, mopeds and motorcycles. Depending on temperature and vapour pressure of fuel, evaporative emissions have shown a growth over the years, nevertheless recently the contribution has been reduced by the introduction of control systems such as the canister. The estimation procedure is differentiated according to the processes of diurnal emission, running losses and hot soak emissions (EMEP/EEA, 2023).

3.5.2.3 *Emissions from automobile tyre and brake wear*

Not exhaust PM emissions from road vehicle tyre and brake wear are estimated. The focus is on the primary particles, deriving directly from tyre and brake wear. The material produced by the effects of wear and attrition between surfaces is subject to evaporation at high temperatures developed by the contact. Emissions are influenced by, as regards tyres, composition and pressure of tyres, structure and characteristics of vehicles, the peculiarities of the road and, as regards brakes, by the composition of the materials of the components, the position, the configuration systems, and the mechanisms of actuation (EMEP/EEA, 2023).

3.5.2.4 *Emissions from automobile road abrasion*

Particulate non-exhaust emissions deriving from road surface wear have been introduced in COPERT model, according to the Guidebook methodology (EMEP/EEA, 2023). Emissions depend on the type of asphalt-based and concrete-based road surfaces, taking into account that composition can vary widely, both from country to country and within countries. The type of tyres used also affect emissions, for instance the wear of the road surface, and the resulting PM concentrations due to resuspension, are considerably high when studded tyres are extensively used during the winter. The wear of the road surface increases with moisture level, also increasing after salting of the road, since the surface remains wet for longer periods. Other influencing factors are vehicle speed, tyre pressure and air temperature. As a consequence of the decrease of temperature, tyres become less elastic, causing the increase of the road surface wear rates (EMEP/EEA, 2023).

3.5.3 Activity data

The road traffic data used are vehicle-kilometre estimates for the different vehicle types and different road classifications in the national road network. These data have to be further broken down by composition of each vehicle fleet in terms of the fraction of different fuels types powered vehicles on the road and in terms of the fraction of vehicles on the road set by the different emission regulations which applied when the vehicle was first registered. These are related to the age profile of the vehicle fleet.

Basic data derive from different sources. Detailed data on the national fleet composition are found in the yearly report from ACI (ACI, several years), used from 1990 to 2006, except for mopeds for which estimates have been elaborated, for the whole time series, on the basis of National Association of Cycle-Motorcycle Accessories data on mopeds fleet composition and mileages (ANCMA, several years).

The Ministry of Transport provides specific fleet composition data for all vehicle categories from 2007 onwards, starting from 2013 submission. The Ministry of Transport in the national transport yearbook (MIT, several years) reports mileages time series. Furthermore since 2015 Ministry of Transport supplies information relating the distribution of old gasoline cars over the detailed vehicles categories (PRE ECE; ECE 15/00-01; ECE 15/02; ECE 15/03; ECE 15/04; information obtained from the registration year; data used for the updating of the time series since 2007). Ministry of Transport data are used relating to: the passenger cars (battery electric, petrol hybrid and diesel hybrid passenger cars are introduced from 2007 onwards, the detailed "Gasoline < 0.8 l" passenger cars subsector is introduced since 2012 and "Diesel < 1.4 l" subsector since 2007 onwards, Petrol PHEV passenger cars are introduced since 2013, in addition to the gasoline, diesel, LPG, CNG traditional ones); the diesel and gasoline light commercial vehicles; the breakdown of the heavy duty trucks, buses and coaches fleet according to the different weight classes and fuels (diesel almost exclusively for HDT, a negligible share consists of gasoline vehicles; diesel for coaches; diesel, diesel hybrid and CNG for urban buses); the motorcycles fleet in the detail of subsector and legislation standard of both 2-stroke and 4-stroke categories. Fleet values for mopeds are updated according to the revisions of data published by ANCMA and Ministry of Transport data; fleet values for diesel buses are updated according to the updating of the data on urban public buses, published on CNIT. The National Institute of Statistics carries out annually a survey on heavy goods vehicles, including annual mileages (ISTAT, several years). The National Association of concessionaries of motorways and tunnels produces monthly statistics on highway mileages by light and heavy vehicles (AISCAT, several years). The National General Confederation of Transport and Logistics (CONFETRA, several years) and the national Central Committee of road transporters (Giordano, 2007) supplied useful information and statistics about heavy goods vehicles fleet composition and mileages.

Fuel consumption data derive basically from the National Energy Balance (MASE, several years (a)); supplementary information is taken from the Oil Bulletin (MASE, several years (b)). As regards biofuels, the consumption has increased in view of the targets to be respected by Italy and set in the framework of the European directive 20-20-20. The trend of biodiesel is explained by the fact that this biofuel has been tested since 1994 to 1996 before entering in production since 1998. The consumption of bioethanol is introduced since 2008, according to data resulting on the BEN. Biogas is introduced since 2020 in the IEA - Eurostat – UNECE Energy Questionnaire.

Emissions are calculated from vehicles of the following types:

- Gasoline passenger cars
- Diesel passenger cars
- LPG passenger cars
- CNG passenger cars
- Petrol Hybrid passenger cars
- Petrol PHEV passenger cars
- Diesel Hybrid passenger cars
- Battery electric passenger cars
- Gasoline Light Commercial Vehicles (Gross Vehicle Weight (GVW) <= 3.5 tonnes)
- Diesel Light Commercial Vehicles (Gross Vehicle Weight (GVW) <= 3.5 tonnes)
- Battery electric Light Commercial Vehicles (Gross Vehicle Weight (GVW) <= 3.5 tonnes)
- Diesel, Gasoline, Natural Gas Rigid-axle Heavy Duty Trucks (GVW > 3.5 tonnes)
- Diesel, Natural Gas Articulated Heavy Duty Trucks (GVW > 3.5 tonnes)
- Diesel Buses and coaches
- Diesel Hybrid Buses
- CNG Buses
- Battery electric Buses
- Mopeds and motorcycles.

In Table 3.16 the historical series of annual consumption data (Mg) for the different fuel types is reported.

Table 3.16 Annual fuel consumption data (Mg)

Fuel	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Gasoline Leaded	12,280,212	10,112,250	4,542,113	-	-	-	-	-	-	-
Gasoline Unleaded	639,115	7,060,391	12,175,814	13,482,132	9,806,890	7,809,940	5,797,395	7,024,957	7,860,951	8,157,635
Diesel	15,278,022	14,445,441	17,059,010	22,327,864	21,557,266	21,128,587	17,103,910	21,033,279	21,799,554	21,685,427
LPG	1,342,000	1,478,000	1,422,000	1,029,000	1,214,000	1,654,000	1,309,461	1,406,968	1,535,280	1,552,363
CNG	183,770	216,804	292,214	342,756	610,502	787,148	671,443	795,900	613,184	600,098
of which biogas	-	-	-	-	-	-	71,340	119,044	160,953	196,642
Biodiesel	-	44,491	64,723	200,000	1,468,086	1,292,079	1,408,889	1,571,059	1,532,236	1,419,855
Biogasoline	-	-	-	-	142,106	30,420	22,841	31,524	40,718	91,647

Source: ISPRA elaborations on BEN, BP, UNEM data

The final reports on the physic-chemical characterization of fossil fuels used in Italy, carried out by the Fuel Experimental Station, that is an Italian Institute operating in the framework of the Department of Industry, are used with the aim to improve fuel quality specifications (surveys conducted in 2000, in 2012 – 2013 and in 2020). Fuel information has also been updated for the entire time series on the basis of the annual reports published by ISPRA about the fuel quality in Italy. Monitoring of the carbon content of the fuels used in Italy is an ongoing activity at ISPRA (Italian Institute for Environmental Protection and

Research). The purpose is to analyse regularly the chemical composition of the used fuels or relevant commercial statistics to estimate the carbon content/emission factor (EF) of the fuels. With reference to the whole inventory, for each primary fuel, a specific procedure has been established.

As regards road transport, Italy fuel specifications values for gasoline, diesel fuel and LPG, derive from Fuel Experimental Station analysis about the properties of transportation fuels sold in Italy and whose results are representative and applicable with reference to four different time phases: 1990 – 1999; 2000 – 2012; 2013 – 2019; since 2020 (Innovhub – Fuel Experimental Station surveys, several years). As regards natural gas, the national market is characterized by the commercialisation of gases with different chemical composition in variable quantities from one year to the other. The methodology used to estimate the average EF for natural gas per year is based on the available consumption data, referring to the lower heat value (each year the quantities of natural gas imported or produced in Italy are published on the web by the Ministry of Environment (https://dgsaie.mise.gov.it/bilancio-gas-naturale). A normalisation procedure is applied to ensure that the breakdown of fuel consumption by each vehicle type calculated on the basis of the fuel consumption factors then added up matches the BEN figures for total fuel consumption in Italy (adjusted for off-road consumption). The automatic energy balance process, introduced by COPERT 5, has been applied. The simulation is started up having the target to equalize calculated and statistical consumptions, separately for fuel, at national level, with the aim to obtain final estimates the most accurate as possible. Once all data and input parameters have been inserted and all options have been set reflecting the peculiar situation of the Country, emissions and consumptions are calculated by the model in the detail of the vehicle category legislation standard; then the aggregated consumption values so calculated are compared with the input statistical national aggregated values (deriving basically from the National Energy Balance, as described above), with the aim to minimize the deviation.

In the following Table 3.17, Table 3.18, Table 3.19 and Table 3.20 detailed data on the relevant vehicle mileages in the circulating fleet are reported, subdivided according to the main emission regulations (ISPRA elaborations on ACI, ANCMA and Ministry of Transport data).

Table 3.17 Passenger Cars technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
a. Gasoline cars technological evolution										
PRE ECE, pre-1973	0.04	0.03	0.01	0.01	0.002	0.002	0.002	0.002	0.002	0.002
ECE 15/00-01, 1973-1978	0.10	0.04	0.01	0.005	0.003	0.002	0.002	0.002	0.002	0.002
ECE 15/02-03, 1978-1984	0.30	0.15	0.03	0.01	0.01	0.01	0.01	0.005	0.005	0.004
ECE 15/04, 1985-1992	0.55	0.55	0.28	0.10	0.04	0.03	0.02	0.02	0.02	0.01
PC Euro 1 - 91/441/EEC, from 1/1/93	0.00	0.24	0.27	0.17	0.05	0.02	0.01	0.01	0.01	0.01
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.39	0.32	0.21	0.11	0.06	0.05	0.04	0.04
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.31	0.20	0.15	0.08	0.07	0.07	0.06
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.09	0.44	0.41	0.27	0.25	0.24	0.22
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.04	0.21	0.17	0.17	0.17	0.16
PC Euro 6 (Since EC 715/2007, from 9/1/2015)	-	-	-	-	-	0.06	0.24	0.23	0.23	0.22
- Euro 6 a/b/c										
- Euro 6 d-temp (2019 - 2020)	-	-	-	-	-	-	0.14	0.14	0.13	0.13
- Euro 6 d (since 2021)	-	-	-	-	-	-	-	0.05	0.09	0.13
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
b. Diesel cars technological evolution										
Conventional, pre-1993	1.00	0.92	0.35	0.05	0.01	0.004	0.002	0.002	0.002	0.001
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.08	0.10	0.03	0.01	0.002	0.001	0.001	0.001	0.001
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.55	0.23	0.08	0.02	0.005	0.006	0.005	0.003
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.56	0.33	0.16	0.08	0.06	0.05	0.05
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.13	0.50	0.43	0.25	0.21	0.20	0.19
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.07	0.35	0.28	0.28	0.27	0.25
PC Euro 6 (Since EC 715/2007, from 9/1/2015)										
- Euro 6 a/b/c	-	-	-	-	0.00	0.05	0.28	0.29	0.29	0.30
- Euro 6 d-temp (2019 - 2020)	-	-	-	-	-	-	0.10	0.11	0.11	0.11
- Euro 6 d (since 2021)	-	-	-	-	-	-	-	0.03	0.06	0.09
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
c. Lpg cars technological evolution										
Conventional, pre-1993	1.00	0.90	0.71	0.47	0.04	0.01	0.01	0.01	0.01	0.01
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.10	0.20	0.26	0.02	0.01	0.004	0.004	0.003	0.003
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.09	0.19	0.08	0.03	0.01	0.01	0.01	0.01
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.06	0.08	0.05	0.02	0.02	0.02	0.02
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.01	0.75	0.46	0.29	0.26	0.24	0.22
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.03	0.36	0.26	0.25	0.24	0.22
PC Euro 6 (Since EC 715/2007, from 9/1/2015)										
- Euro 6 a/b/c	-	-	-	-	-	0.08	0.13	0.12	0.12	0.11
- Euro 6 d-temp (2017-2019)	-	-	-	-	-	-	0.22	0.21	0.21	0.20
- Euro 6 d (2020 and later)	-	-	-	-	-	-	0.05	0.10	0.15	0.21
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
d. CNG cars technological evolution										
PC Conventional - Euro 4	1.00	1.00	1.00	1.00	0.91	0.58	0.42	0.39	0.37	0.36
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.09	0.32	0.29	0.28	0.28	0.29
PC Euro 6 (Since EC 715/2007, from 9/1/2015)										
- Euro 6 a/b/c	-	-	-	-	-	0.10	0.14	0.13	0.14	0.14

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
- Euro 6 d-temp (2017-2019)	-	-	-	-	-	-	0.12	0.12	0.12	0.12
- Euro 6 d (2020 and later)	-	-	-	-	-	-	0.04	0.07	0.09	0.09
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		2007	2008	2009	2010	2015	2020	2021	2022	2023
e. Hybrid Gasoline cars technological evolution (from 2007 onwards)										
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006		1.00	1.00	0.65	0.54	0.11	0.01	0.01	0.004	0.002
PC Euro 5 - EC 715/2007, from 1/1/2011		-	-	0.35	0.46	0.74	0.07	0.04	0.03	0.02
PC Euro 6 (Since EC 715/2007, from 9/1/2015)										
- Euro 6 a/b/c		-	-	-	-	0.15	0.35	0.21	0.14	0.10
- Euro 6 d-temp (2019 - 2020)		-	-	-	-	-	0.57	0.32	0.22	0.16
- Euro 6 d (since 2021)		-	-	-	-	-	-	0.42	0.61	0.72
Total		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
				2013	2014	2015	2020	2021	2022	2023
f. Petrol PHEV cars technological evolution (from 2013 onwards)										
- Euro 6 a/b/c				1.00	1.00	1.00	0.33	0.02	0.01	0.01
- Euro 6 d-temp (2019 - 2020)				-	-	-	0.67	0.29	0.17	0.12
- Euro 6 d (since 2021)				-	-	-	-	0.69	0.82	0.87
Total				1.00	1.00	1.00	1.00	1.00	1.00	1.00
		2007	2008	2009	2010	2015	2020	2021	2022	2023
g. Hybrid Diesel cars technological evolution (from 2007 onwards)										
PC Euro 6 (Since EC 715/2007, from 9/1/2015)										
- Euro 6 a/b/c		1.00	1.00	1.00	1.00	1.00	0.09	0.04	0.02	0.01
- Euro 6 d-temp (2019 - 2020)		-	-	-	-	-	0.91	0.41	0.26	0.17
- Euro 6 d (since 2021)		-	-	-	-	-	-	0.55	0.71	0.81
Total		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3.18 Light Commercial Vehicles technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
a. Gasoline Light Commercial Vehicles technological evolution										
Conventional, pre 10/1/94	1.00	0.93	0.63	0.35	0.08	0.05	0.03	0.03	0.03	0.02
LCV Euro 1 - 93/59/EEC, from 10/1/94	-	0.07	0.21	0.17	0.10	0.05	0.02	0.02	0.02	0.01
LCV Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.16	0.15	0.30	0.17	0.05	0.04	0.04	0.04
LCV Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.31	0.26	0.20	0.10	0.07	0.08	0.07
LCV Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.25	0.31	0.23	0.20	0.17	0.15
LCV Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.004	0.21	0.16	0.15	0.13	0.11
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016)										
- Euro 6 a/b/c	-	-	-	-	-	0.02	0.10	0.09	0.08	0.07
- Euro 6 d-temp (2018 - 2020)	-	-	-	-	-	-	0.30	0.31	0.26	0.23
- Euro 6 d (since 2021)	-	-	-	-	-	-	-	0.09	0.20	0.29
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
b. Diesel Light Commercial Vehicles technological evolution										
Conventional, pre 10/1/94	1.00	0.92	0.54	0.22	0.07	0.03	0.01	0.01	0.01	0.01
LCV Euro 1 - 93/59/EEC, from 10/1/94	-	0.08	0.22	0.10	0.05	0.03	0.01	0.005	0.004	0.004
LCV Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.24	0.21	0.17	0.09	0.01	0.01	0.01	0.01
LCV Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.46	0.33	0.22	0.05	0.05	0.04	0.04
LCV Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.38	0.33	0.18	0.18	0.16	0.14
LCV Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.01	0.30	0.29	0.26	0.24	0.22
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016)										
- Euro 6 a/b/c	-	-	-	-	0.00	0.01	0.16	0.14	0.13	0.12
- Euro 6 d-temp (2018 - 2020)	-	-	-	-	-	-	0.29	0.26	0.25	0.23
- Euro 6 d (since 2021)	-	-	-	-	-	-	-	0.09	0.16	0.23
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3.19 Heavy Duty Trucks and Buses technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
a. Heavy Duty Trucks technological evolution										
Conventional, pre 10/1/93	1.00	0.90	0.68	0.37	0.20	0.02	0.01	0.01	0.01	0.01
HDT Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.10	0.10	0.07	0.04	0.01	0.003	0.004	0.004	0.004
HDT Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.22	0.28	0.15	0.08	0.04	0.04	0.04	0.03
HDT Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.28	0.36	0.34	0.20	0.18	0.17	0.16
HDT Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.07	0.09	0.07	0.06	0.06	0.05
HDT Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.18	0.39	0.32	0.30	0.27	0.25
HDT Euro VI (Since 2009/595/EC, from 12/31/2013)										
- Euro VI A/B/C	-	-	-	-	-	0.07	0.23	0.22	0.20	0.19
- Euro VI D/E (2019 and later)	-	-	-	-	0.001	0.003	0.13	0.19	0.25	0.30
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
b. Diesel Buses technological evolution										
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**	**2023**
Conventional, pre 10/1/93	1.00	0.93	0.65	0.34	0.13	0.01	0.005	0.004	0.004	0.003

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Buses Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.07	0.07	0.08	0.04	0.01	0.01	0.004	0.004	0.003
Buses Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.28	0.32	0.27	0.14	0.07	0.06	0.05	0.04
Buses Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.26	0.34	0.38	0.26	0.21	0.20	0.17
Buses Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.12	0.13	0.11	0.10	0.09	0.09
Buses Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.11	0.28	0.25	0.26	0.26	0.25
Buses Euro VI (Since 2009/595/EC, from 12/31/2013)	-	-	-	-	-	0.05	0.20	0.21	0.20	0.19
- Euro VI A/B/C	-	-	-	-	-	-	0.10	0.15	0.19	0.24
- Euro VI D/E (2019 and later)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
c. CNG Buses technological evolution										
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**	**2023**
Urban CNG Buses Conventional, pre 10/1/93; Urban CNG Buses Euro I - 91/542/EEC Stage I, from 10/1/93	1.00	1.00	0.11	0.01	0.003	0.003	0.001	0.001	0.001	0.0004
Urban CNG Buses Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.89	0.20	0.10	0.05	0.01	0.01	0.004	0.002
Urban CNG Buses Euro III - 2000 Standards, 99/96/EC, from 10/1/2001; Urban CNG Buses Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	0.79	0.09	0.07	0.05	0.04	0.03	0.02
Urban CNG Buses Euro V - 2008 Standards, 99/96/EC, from 10/1/2009; EEV (Enhanced environmentally friendly vehicle; ref. 2001/27/EC and 1999/96/EC line C, optional limit emission values).	-	-	-	-	0.81	0.84	0.58	0.53	0.39	0.29
Urban CNG Buses Euro VI D/E (since 2013)	-	-	-	-	-	0.03	0.35	0.42	0.57	0.68
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
d. Diesel Hybrid Buses technological evolution (from 2007 onwards)										
		2007	**2008**	**2009**	**2010**	**2015**	**2020**	**2021**	**2022**	**2023**
Buses Euro VI (Since 2009/595/EC, from 12/31/2013)										
- Euro VI A/B/C		1.00	1.00	1.00	1.00	1.00	0.16	0.10	0.08	0.04
- Euro VI D/E		-	-	-	-	-	0.84	0.90	0.92	0.96
Total		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 3.20 Mopeds and Motorcycles technological evolution: stock data multiplied by actual mileage (%)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Mopeds and motorcycles - Conventional	1.00	1.00	0.88	0.43	0.18	0.12	0.09	0.09	0.09	0.08
Mopeds and motorcycles - Euro 1	-	-	0.12	0.30	0.20	0.14	0.10	0.09	0.09	0.08
Mopeds and motorcycles - Euro 2	-	-	-	0.22	0.35	0.32	0.22	0.20	0.19	0.18
Mopeds and motorcycles - Euro 3	-	-	-	0.04	0.27	0.41	0.40	0.38	0.36	0.33
Mopeds and motorcycles - Euro 4	-	-	-	-	-	-	0.18	0.18	0.17	0.16
Mopeds and motorcycles - Euro 5	-	-	-	-	-	-	0.01	0.05	0.10	0.16
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Average emission factors are calculated for average speeds by three driving modes (urban, rural and motorway) combined with the vehicle kilometres travelled and vehicle categories. ISPRA estimates total annual vehicle kilometres for the road network in Italy by vehicle type, based on data from various sources:

- Ministry of Transport (MIT, several years) for rural roads and on other motorways; the latter estimates are based on traffic counts from the rotating census and core census surveys of ANAS (management authority for national road and motorway network);
- highway industrial association for fee-motorway (AISCAT, several years);
- local authorities for built-up areas (urban).

Table 3.21 Evolution of fleet consistency and mileage

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
All passenger vehicles (including moto), total mileage (10^9 veh-km/y)	350	412	454	446	438	429	342	417	420	424
Car fleet (10^6)	27	30	32	34	36	37	40	40	40	41
Moto, total mileage (10^9 veh-km/y)	30	41	42	42	34	32	23	25	26	26
Moto fleet (10^6)	7	7	9	9	9	10	10	10	10	11
Goods transport, total mileage (10^9 veh-km/y)	69	76	81	103	76	67	56	69	78	79
Truck fleet (10^6), including LDV	2	3	3	4	5	5	5	5	5	5

Source: ISPRA elaborations

Notes: The passenger vehicles include passenger cars, buses and moto; the moto fleet includes mopeds and motorcycles; in the goods transport light commercial vehicles and heavy duty trucks are included.

3.5.4 Time series and key categories

The analysis of time series on transport data shows a trend that is the result of the general growth in mobility demand and consumptions until 2007, followed by a decrease basically due to the economic crisis on one side, and of the introduction of advanced technologies limiting emissions in modern vehicles in recent years, on the other side; then the growth in the years 2018-2019 is followed by a sharp decrease in 2020 due to the pandemic crisis and a subsequent recovery since 2020.

More in details, passenger cars and light duty vehicles emissions trends are driven by a gradual decrease over the years of gasoline fuel consumption balanced by an increase of diesel fuel which is the main driver for NO_X and PM emissions. At pollutant level emission trends are driven not only by fuel but also by changes in technologies which are reflected in the COPERT model by the evolution of the annual vehicle fleet. Due to the penetration of new vehicles with more stringent pollutant limits, some pollutant emissions decreased faster than other. An important role has been played also by the distribution between diesel and gasoline fuel consumptions. In the last years an increase of diesel fuelled vehicles and a decrease of gasoline ones have been registered and diesel fuel new technologies resulted in a slower decrease of NO_X emission than expected. Regarding heavy duty vehicles emissions trends are explained by the variations estimated in mileages time series data correlated to the variations registered in fuel consumptions; annual variation is explained by the general trend of national economic growth and in particular commercial and industrial activities. Emissions trends regarding mopeds and motorcycles are explained by the variations estimated in mileages time series data correlated to the variations registered in gasoline consumptions. The annual penetration of new technologies explains annual emission trends. The general decrease between 2019 and 2020 is explained by the pandemic crisis.

In Table 3.22 the list of key categories by pollutant identified for road transport in 2023, 1990 and at trend assessment is reported.

Table 3.22 List of key categories for pollutant in the road transport in 2023, 1990 and in trend

	Key categories in 2023			Key categories in 1990				Key categories in trend			
NO_X	1A3bi	1A3bii	1A3biii	1A3bi	1A3bii	1A3biii		1A3bi	1A3bii	1A3biii	
NMVOC	1A3biv	1A3bv		1A3bi	1A3biv	1A3bv		1A3bi	1A3biv		
NH_3								1A3bi			
CO	1A3bi	1A3biv		1A3bi	1A3biv			1A3bi			
PM_{10}	1A3bvi	1A3bvii		1A3bi	1A3bii	1A3biii	1A3bvi	1A3bi	1A3bii	1A3biii	1A3bvi
$PM_{2.5}$	1A3bvi			1A3bi	1A3bii	1A3biii	1A3bvi	1A3bi	1A3bii	1A3biii	1A3bvi
BC	1A3bi	1A3biii	1A3bvi	1A3bi	1A3bii	1A3biii		1A3bi	1A3bii	1A3biii	1A3bvi
Pb	1A3bvi			1A3bi	1A3biv			1A3bi	1A3bvi		
Cd	1A3bi	1A3bvi						1A3bi			

Source: ISPRA elaborations

In 2023 key categories are identified for the following pollutants: nitrogen oxides, non methane volatile organic compounds, carbon monoxide, particulate matter with diameter less than 10 µm, particulate matter with diameter less than 2.5 µm, black carbon, lead and cadmium.

Nitrogen oxides emissions show a decrease since 1990 of -77.5%. Emissions are mainly due to diesel vehicles. The decrease observed since 1990 in emissions relates to all categories except for diesel passenger cars, hybrid categories and CNG buses and heavy duty trucks. In 2023, emissions of nitrogen oxides (Table 3.23) from passenger cars, light-duty vehicles and heavy-duty trucks including buses are key categories. The same categories are identified as key categories in 1990 and in trend.

Table 3.23 Time series of nitrogen oxides emissions in road transport (Gg)

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
	Gg									
1.A.3.b.i Passenger cars	590.9	628.3	388.2	234.1	175.2	161.7	106.0	123.8	113.7	107.7
1.A.3.b.ii Light-duty vehicles	60.6	69.5	64.0	71.2	39.3	47.6	32.0	37.8	38.4	35.6
1.A.3.b.iii Heavy-duty vehicles including buses	340.3	336.1	328.6	327.1	221.5	114.1	70.1	74.9	84.4	78.2
1.A.3.b.iv Mopeds and motorcycles	4.3	5.6	5.9	6.9	4.9	4.2	2.4	2.4	2.5	2.4
Total emissions	**996.1**	**1,039.5**	**786.8**	**639.3**	**440.9**	**327.7**	**210.6**	**239.0**	**239.0**	**223.9**

As regards non methane volatile organic compounds, emissions from mopeds and motorcycles and gasoline evaporation are key categories in 2023; emissions from passenger cars, mopeds and motorcycles and gasoline evaporation are key categories in 1990; emissions from passenger cars and mopeds and motorcycles are key categories in trend. Despite the decline of about -88.2% since 1990 of emissions of non-methane volatile organic compounds from this category, road transport (Table 3.24) is the fourth source at national level after the use of solvents, the not industrial combustion and agriculture; this trend is due to the combined effects of technological improvements that limit VOCs from tail pipe and evaporative emissions (for cars) and the expansion of two-wheelers fleet. In Italy there is in fact a remarkable fleet of motorbikes and mopeds (about 10.5 million vehicles in 2023) that uses gasoline and it is increased of about 59.1% since 1990 (this fleet not completely complies with strict VOC emissions controls).

Table 3.24 Time series of non methane volatile organic compounds emissions in road transport (Gg)

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
	Gg									
1.A.3.b.i Passenger cars	430.4	468.2	265.0	121.8	47.9	26.2	13.2	14.1	13.6	13.0
1.A.3.b.ii Light-duty vehicles	15.6	18.5	12.4	11.1	4.4	2.6	0.6	0.7	0.7	0.6
1.A.3.b.iii Heavy-duty vehicles including buses	26.3	25.2	21.7	18.0	9.9	3.4	2.1	2.3	2.6	2.5
1.A.3.b.iv Mopeds and motorcycles	175.5	248.8	225.2	152.6	73.7	50.1	25.0	25.0	24.8	24.3
1.A.3.b.v Gasoline evaporation	119.2	119.1	87.9	55.5	45.0	45.5	45.6	44.6	49.0	50.2
Total emissions	**767.0**	**879.7**	**612.2**	**359.1**	**180.9**	**127.9**	**86.4**	**86.7**	**90.7**	**90.6**

Source: ISPRA elaborations

Carbon monoxide emissions from passenger cars and mopeds and motorcycles are key categories in 2023 and 1990; passenger cars are also key category in trend. The time series of CO emissions is reported in Table 3.25.

Table 3.25 Time series of carbon monoxide emissions in road transport (Gg)

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
	Gg									
1.A.3.b.i Passenger cars	4,124.6	4,171.4	2,191.3	1,088.4	473.1	270.4	149.0	165.0	165.2	162.2
1.A.3.b.ii Light-duty vehicles	175.1	207.7	124.7	95.6	38.1	21.3	5.8	6.9	7.1	6.7
1.A.3.b.iii Heavy-duty vehicles including buses	81.4	79.8	74.2	74.5	55.9	33.5	22.2	24.0	27.0	25.3
1.A.3.b.iv Mopeds and motorcycles	493.4	667.3	619.3	434.9	197.5	141.5	81.3	81.8	81.9	80.4
Total emissions	**4,874.5**	**5,126.1**	**3,009.5**	**1,693.4**	**764.7**	**466.7**	**258.3**	**277.7**	**281.2**	**274.7**

Source: ISPRA elaborations

A strong contribution to total emissions is given by gasoline vehicles (about 76.2% in 2023, although since 1990 a decrease of about – 95.4% is observed); since 1990 to 2023 a general decrease, of about -94.4%, is observed.

Emissions of PM10 (Table 3.26) deriving from passenger cars, light-duty vehicles, heavy-duty vehicles including buses, road vehicle tyre and brake wear are key categories in 1990; emissions from road vehicle tyre and brake wear and emissions from road surface wear are key categories in 2023; emissions from passenger cars, light-duty vehicles, heavy-duty vehicles including buses and from road vehicle tyre and brake wear are key category in trend.

As regards PM2.5 (Table 3.27), in 2023 emissions from road vehicle tyre and brake wear are key categories; emissions from passenger cars, light-duty vehicles, heavy-duty vehicles including buses and road vehicle tyre and brake wear are key categories in 1990 and in trend.

With regard to particulate matter, the relative weight of the non-exhaust component in total emissions becomes progressively more significant over the years.

Table 3.26 Time series of particulate matter with diameter less than 10 µm emissions in road transport (Gg)

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Gg					
1.A.3.b.i Passenger cars	19.3	14.1	11.9	9.2	8.6	5.5	2.5	2.6	2.3	2.0
1.A.3.b.ii Light-duty vehicles	10.4	11.5	9.2	8.2	3.3	2.3	0.5	0.7	0.6	0.6
1.A.3.b.iii Heavy-duty vehicles including buses	13.6	13.3	11.4	9.6	5.4	2.1	1.2	1.3	1.4	1.3
1.A.3.b.iv Mopeds and motorcycles	3.7	5.3	4.8	3.2	1.4	1.0	0.5	0.5	0.5	0.5
1 A 3 b vi Road Transport, Automobile tyre and brake wear	8.9	10.1	11.0	12.0	11.1	11.0	7.9	9.7	10.1	10.2
1.A.3.b.vii Road transport: Automobile road abrasion	4.1	4.6	5.0	5.4	4.8	4.3	3.6	4.4	4.7	4.7
Total emissions	**59.9**	**58.9**	**53.4**	**47.5**	**34.7**	**26.2**	**16.3**	**19.1**	**19.6**	**19.3**

Source: ISPRA elaborations

Table 3.27 Time series of particulate matter with diameter less than 2.5 µm emissions in road transport (Gg)

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Gg					
1.A.3.b.i Passenger cars	19.3	14.1	11.9	9.2	8.6	5.5	2.5	2.6	2.3	2.0
1.A.3.b.ii Light-duty vehicles	10.4	11.5	9.2	8.2	3.3	2.3	0.5	0.7	0.6	0.6
1.A.3.b.iii Heavy-duty vehicles including buses	13.6	13.3	11.4	9.6	5.4	2.1	1.2	1.3	1.4	1.3
1.A.3.b.iv Mopeds and motorcycles	3.7	5.3	4.8	3.2	1.4	1.0	0.5	0.5	0.5	0.5
1 A 3 b vi Road Transport: Automobile tyre and brake wear	4.6	5.3	5.7	6.2	5.8	5.7	4.2	5.1	5.3	5.4
1.A.3.b.vii Road transport: Automobile road abrasion	2.2	2.5	2.7	2.9	2.6	2.3	2.0	2.4	2.5	2.6
Total emissions	**53.7**	**51.9**	**45.8**	**39.3**	**27.2**	**18.9**	**10.8**	**12.5**	**12.7**	**12.3**

Source: ISPRA elaborations

Emissions of particulate matter with diameter less than 10µm and less than 2.5µm show a decreasing trend since 1990 respectively of about -67.8% and -77.1%. Despite the decrease, diesel vehicles (passenger cars, light duty vehicles and heavy duty trucks including buses) are mainly responsible for road transport emissions giving a strong contribution to total emissions, in 2023 about 73.1% and 75.1% out of the total for PM10 and PM2.5 respectively.

Emissions of black carbon are reported in Table 3.28. Emissions from passenger cars, heavy-duty trucks including buses and road vehicle tyre and brake wear are key categories in 2023; emissions from passenger cars, light-duty vehicles and heavy-duty trucks including buses are key categories in 1990; emissions from passenger cars, light-duty vehicles and heavy-duty trucks including buses and road vehicle tyre and brake wear are key categories in trend. The emissions trend is generally decreasing (-81.7% since 1990). The main contribution to total emissions is given by diesel vehicles, in 2023 equal to 86.7% out of the total. Despite the decrease, road transport is the second source of emissions (the main source is non industrial combustion) at national level in 2023 (24.7%).

Table 3.28 Time series of black carbon emissions in road transport (Gg)

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Gg					
1.A.3.b.i Passenger cars	8.8	6.4	6.2	5.9	5.8	4.0	1.7	1.8	1.6	1.4
1.A.3.b.ii Light-duty vehicles	5.1	5.7	4.9	4.8	2.2	1.6	0.4	0.5	0.4	0.4

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Gg					
1.A.3.b.iii Heavy-duty vehicles including buses	6.8	6.8	6.0	5.5	3.3	1.4	0.8	0.9	1.0	0.9
1.A.3.b.iv Mopeds and motorcycles	0.7	0.9	0.9	0.6	0.2	0.2	0.1	0.1	0.1	0.1
1 A 3 b vi Road Transport: Automobile tyre and brake wear	1.1	1.2	1.3	1.4	1.3	1.3	1.0	1.2	1.3	1.3
1.A.3.b.vii Road transport: Automobile road abrasion	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total emissions	**22.6**	**21.1**	**19.5**	**18.2**	**13.0**	**8.5**	**4.1**	**4.5**	**4.4**	**4.1**

Source: ISPRA elaborations

Emissions of cadmium are reported in Table 3.29. Cadmium emissions from passenger cars are key categories in 2023 and in trend. Emissions from automobile tyre and brake wear are also key categories in 2023. Emissions show an increase since 1990 of about +0.8%, representing in 2023 the 12.3% of the national total. In 2023 most of the emissions derive from passenger cars (72.1%); non exhaust emissions from automobile tyre and brake wear are equal to 32.6% of the total.

Table 3.29 Time series of Cadmium emissions in road transport (Mg)

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Mg					
1.A.3.b.i Passenger cars	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3
1.A.3.b.ii Light-duty vehicles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A.3.b.iii Heavy-duty vehicles including buses	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.A.3.b.iv Mopeds and motorcycles	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1.A.3.b.vi Road transport: Automobile tyre and brake wear	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
1.A.3.b.vii Road transport: Automobile road abrasion	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total emissions	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.4**	**0.5**	**0.5**	**0.5**

Source: ISPRA elaborations

Emissions of SO_X, NH_3 and Pb are shown in Table 3.30. SO_X are not key categories. Pb emissions from road vehicle tyre and brake wear are key category in 2023, Pb emissions from passenger cars and from mopeds and motorcycles are key categories in 1990, Pb emissions from passenger cars and road vehicle tyre and brake wear are key categories in trend. Emissions of NH_3 from passenger cars are key categories in trend. In 2023 emissions of these pollutants deriving from road transport are less important compared to other sectors. Emissions of SO_X and Pb show strong decreases. Since 2002, due to limits on fuels properties imposed by legislation, Pb resulting emissions are almost completely non exhaust (road vehicle tyre and brake wear Pb emissions increase of about 9.8% since 1990); total Pb emissions decrease of -99.0% since 1990, representing in 2023 about 18.8% of the national total. SO_X emissions decrease by -99.7%, representing 0.5% of the total in 2023. Emissions of NH_3, despite the strong increase since 1990, in 2023 account for just 1.4% out of the total.

Table 3.30 Time series of sulphur oxides, ammonia and lead emissions in road transport

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
SO_X (Gg)	129.3	71.6	11.9	2.2	0.4	0.4	0.3	0.4	0.4	0.4
NH_3 (Gg)	0.8	5.3	20.6	15.7	9.6	6.1	4.2	5.0	5.3	5.5
Pb (Mg)	3,806.2	1,644.8	719.8	45.7	42.5	42.9	29.4	35.7	37.2	37.3

3.5.5 QA/QC and Uncertainty

Data used for estimating emissions from the road transport sector, derive from different sources, including official statistics providers and industrial associations. A specific procedure undertaken for improving the inventory in the sector regards the establishment of a national expert panel in road transport which involves, on a voluntary basis, different institutions, local agencies and industrial associations cooperating for improving activity data and emission factors accuracy. In this group emission estimates are presented annually and new methodologies are shared and discussed. Reports and data of

the meetings can be found at the following address: http://groupware.sinanet.isprambiente.it/expert_panel/library; 2024 meeting has been held in Rome (Automobile Club of Italy, https://www.aci.it/).
In addition, road transport emission factors are shared and publicly available on the website https://fetransp.isprambiente.it/#/.
Besides, over time recalculations of time series estimates have been discussed with national experts in the framework of an ad hoc working group on air emissions inventories. The group is chaired by ISPRA and includes participants from the local authorities responsible for the preparation of local inventories, sectoral experts, the Ministry of Environment and air quality model experts. Recalculations are comparable with those resulting from application of the model at local level. Top-down and bottom-up approaches have been compared with the aim at identifying the major problems and future possible improvements in the methodology to be addressed (emission estimates at the link: https://emissioni.sina.isprambiente.it/inventario-nazionale/). A Montecarlo analysis has been carried out by EMISIA on behalf of the Joint Research Centre (Kouridis et al., 2010) in the framework of the study "Uncertainty estimates and guidance for road transport emission calculations" for 2005 emissions. The study shows an uncertainty assessment, at Italian level, for road transport emissions on the basis of 2005 input parameters of the COPERT 4 model (v. 7.0).

3.5.6 Recalculation

The annual update of the emissions time series from road transport implies a periodic review process.

In 2025 submission the historical series has been revised mainly as a result of the upgrade of COPERT model version used (from version 5.7.3 in last submission to 5.8.1 in submission 2025), which resulted in various methodological updates.
Main methodological innovations introduced in version 5.8.1 respect to version 5.7.3 , used in last submission, relate: the introduction of Euro 7 vehicles; the introduction of Euro VI CNG & LNG HDVs; the revision of CO, EC, SPN23, NOx of Euro 6 HEV/PHEV; the revision of VOCs speciation of Euro 5/6 petrol & diesel LDVs; the revision of EC of BEVs; the revision of cold PM & BC of Euro 5/6 petrol, diesel & CNG LDVs; the revision of EC of Euro 6 LPG cars; the revision of Euro 5 motorcycles.
As regards the software, revisions relate: the extension of the functionalities of the Command Line Interface regarding ability to point to an existing .cop file, all pollutants, mileage degradation; the Energy Consumption from A/C for battery electric cars.
In addition, the following bugs have been solved: share of cold CH4 and NMVOC over VOC for Euro 6 LDVs; hot CH_4 emission factors of LPG cars; PM, PN emission factor of CNG/LPG Euro 5 & 6 vehicles; minor issues.

With respect to the last submission, the following vehicle categories have been introduced: Battery electric Light Commercial Vehicles, CNG and LNG Heavy Duty Trucks, Battery electric Buses.

Country specific emission factors for Euro 6 LPG passenger cars, deriving from Innovhub survey, until 2022 submission inserted in the model as user values, are now implemented in COPERT model.

The COPERT efficiency improvement tool has been applied (OBFCM data at country level, https://climate-energy.eea.europa.eu/topics/transport/real-world-emissions/additional_information), also to compensate the removal of CO_2 correction tool in COPERT model, previously referred to gasoline and diesel passenger cars from Euro 4 onwards.

Italian road vehicles electricity consumption data derive from Eurostat database (https://ec.europa.eu/eurostat/data/database). COPERT input road electricity consumption data have been calibrated on the basis of the vehicles categories using electricity actually included in COPERT classification. In 2025 submission, updated electricity consumption factors have been applied, deriving from Appendix 4 of the 2023 EMEP/EEA air pollutant emission inventory guidebook; that, jointly with the introduction of the new electric vehicle categories, result in a different balance of mileage and in a revision of estimated electricity consumptions , respect to previous submission.

Biogas road consumption, included in COPERT model in the total road natural gas consumption, has been considered in the Inventory, reported only since 2020 in the IEA - Eurostat – UNECE Energy Questionnaire (about 11%, 15%, 26% and 33% of total road natural gas consumption in 2020, 2021, 2022 and 2023 respectively).

Estimate of the mopeds circulating fleet has been revised consistently with data supplied by ANCMA (https://www.ancma.it/).

On the basis of the fleet updated data provided by the Ministry of Transport, revisions have been applied to the estimation of the distribution of hybrid passenger cars as regards the Phev share on total fleet categories.

Mileage balance has been also revised as a consequence of a revision of transport statistics data published by the Ministry of Transport regarding: the circulating urban buses fleet and the tons-km as regards freight transport since 2022.

Revisions applied affected the annual balances and, as a consequence, adjustments of mileages were applied in the historical series.

3.5.7 Planned improvements

Improvements for the next submission will be connected to the possible new availability of data and information regarding activity data, calculation factors and parameters, new developments of the methodology and the update of the software.

3.6 RAILWAYS (NFR SUBSECTOR 1.A.3.C)

The electricity used by the railways for electric traction is supplied by the public distribution system, so the emissions arising from its generation are reported under category 1.A.1.a Public Electricity. Emissions from diesel trains are reported under the IPCC category 1.A.3.c Railways. Estimates are based on the gasoil consumption for railways reported in BEN (MASE, several years [a]), updated since 2018 according to EUROSTAT methodology (https://dgsaie.mise.gov.it/bilancio-energetico-nazionale), and on the methodology Tier1, and emission factors from the EMEP/EEA Emission Inventory Guidebook 2023 (EMEP/EEA, 2023).

Fuel consumption data are collected by the Ministry of Economic Development, responsible for the energy balance, from the companies with diesel railways. The activity is present only in those areas without electrified railways, which are limited in the national territory. The trend reflects the decrease of non-electrified railways across the country. Because of low values, emissions from railways do not represent a key category. In Table 3.31 diesel consumptions (TJ) and nitrogen oxides, non-methane volatile organic compounds, Sulphur oxides, ammonia, particulate and carbon monoxide emissions (Gg) are reported. Emissions of Pb from 2002 are reported as 'NA", because of the introduction of unleaded liquid fuels in the market in 2002. Heavy metals contents values derive from the analysis about the physical - chemical characterization of fossil fuels used in Italy (Innovhub, Fuel Experimental Station, several years).

Table 3.31 Consumptions and emissions time series in railways

Consumptions and Emissions for NFR Subsector 1.A.3.c	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Diesel Consumption (TJ)	8,370.3	8,199.4	5,850.6	4,142.4	2,690.4	939.6	1,851.7	1,601.0	475.2	500.4
Emissions from diesel trains (Gg)										
NO_x	10.27	10.06	7.18	5.08	3.24	1.00	1.72	1.48	0.44	0.46
NMVOC	0.91	0.89	0.64	0.45	0.29	0.09	0.17	0.14	0.04	0.05
SO_x	1.20	0.77	0.08	0.01	0.001	0.0003	0.0006	0.0005	0.0002	0.0002
NH_3	0.001	0.001	0.001	0.001	0.0004	0.0002	0.0003	0.0003	0.0001	0.0001
PM2.5	0.27	0.26	0.19	0.13	0.08	0.03	0.04	0.03	0.01	0.01
PM10	0.28	0.28	0.20	0.14	0.09	0.03	0.04	0.04	0.01	0.01
TSP	0.29	0.28	0.20	0.14	0.09	0.03	0.04	0.04	0.01	0.01
BC	0.18	0.18	0.13	0.09	0.06	0.02	0.03	0.02	0.01	0.01
CO	2.10	2.05	1.47	1.04	0.67	0.24	0.46	0.40	0.12	0.13

In the review process has been observed the existence of at least one steam engine still operating in Italy. It is an historic train used only for few days per year and probably fueled with biomass nowadays instead of coal. Nor are biomass or coal reported in the energy balance for railways activities. Anyway, this possible source of emission could be considered insignificant.

PM10 and PM2.5 emission factors for 2021 and 2022 have been updated in this submission.

No specific improvements are planned for the next submission.

3.7 NAVIGATION (NFR SUBSECTOR 1.A.3.D)

3.7.1 Overview

This source category includes all emissions from fuels delivered to water-borne navigation. National navigation is a key category in 2023 with respect to emissions of SO_X, NO_X, PM10, PM2.5 and BC.

3.7.2 Methodological issues

Emissions of the Italian inventory from the navigation sector are carried out according to the IPCC Guidelines and Good Practice Guidance (IPCC, 1997; IPCC, 2000) and the EMEP/EEA Guidebook (EMEP/EEA, 2023). A national methodology has been developed following the EMEP/EEA Guidebook which provides details to estimate emissions from domestic navigation, specifying recreational craft, ocean-going ships by cruise and harbor activities; emissions from international navigation are also estimated and included as memo item but not included in national totals (EMEP/EEA, 2023). Inland, coastal and deep-sea fishing are estimated and reported under 1.A.4.c. International inland waterways do not occur in Italy. The methodology developed to estimate emissions is based on the following assumptions and information.

Activity data comprises both fuel consumptions and ship movements, which are available in different level of aggregation and derive from different sources as specified here below:

- Total deliveries of fuel oil, gas oil and marine diesel oil to marine transport are given in national energy balance (MASE, several years (a)) but the split between domestic and international is not provided;
- Naval fuel consumption for inland waterways, ferries connecting mainland to islands and leisure boats, is also reported in the national energy balance as it is the fuel for shipping (MASE, several years (a));
- Data on annual arrivals and departures of domestic and international shipping calling at Italian harbors are reported by the National Institute of Statistics in the statistics yearbooks (ISTAT, several years (a)) and Ministry of Transport in the national transport statistics yearbooks (MIMS, several years).

As for emission and consumption factors, figures are derived by the EMEP/EEA guidebook (EMEP/EEA, 2019), both for recreational and harbor activities and national cruise, considering national specificities. These specificities derive from the results of a national study which, considering detailed information on the Italian marine fleet and the origin-destination movement matrix for the year 1997, calculated national values (ANPA, 2001; Trozzi et al., 2002 (b)) based on the default emission and consumption factors reported in the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007). National average emissions and consumption factors were therefore estimated for harbor and cruise activities both for domestic and international shipping from 1990 to 1999. In 2009 submission the study was updated for the years 2004, 2005 and 2006 to consider the most recent trends in the maritime sector both in terms of modelling between domestic and international consumptions and improvements of operational activities in harbor (TECHNE, 2009). Based on the results, national average emissions and consumption factors were updated from 2000. Specifically, for the years referred to in the surveys, the current method estimates emissions from the number of ships movements broken down by ship type at each of the principal Italian ports considering the information of whether the ship movement is international or domestic, the average tonnage and the relevant distance travelled. For those years, in fact, figures on the number of arrivals, destination, and fleet composition have been provided by the local port authorities and by the National Institute of Statistics (ISTAT, 2009), covering about 90% of the official national statistics on ship movements for the relevant years. Consumption and emission factors are those derived from the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007) and refer to the Tier 3 ship movement methodology that considers origin-destination ship movements matrices as well as technical information on the ships, as engine size, gross tonnage of ships and operational times in harbors. Based on sample information, estimates have been carried out at national level for the relevant years considering the official statistics of the maritime sector. Moreover, an update of the emission factor of hoteling phase has been carried out more recently and the emission factors have been updated accordingly (ISPRA, 2023).

In general, to carry out national estimates of greenhouse gases and other pollutants in the Italian inventory for harbor and domestic cruise activities, consumptions and emissions are calculated for the complete time series using the average consumption and emission factors multiplied by the total number of movements. On the other hand, for international cruise, fuel consumption is derived by difference from the total fuel consumption reported in the national energy balance and the estimated values as described above and emissions are therefore calculated. For maritime transportation only by Directive 1999/32/EC European Union started to examine environmental impact of navigation, and particularly the Sulphur content of fuels. This directive was amended by Directive 2005/33/EC that designated the Baltic Sea, the English Channel and the North Sea as Sulphur emission control areas (SECA) limiting the content of Sulphur in the fuel for these areas and introducing a limit of 0.1% of the Sulphur content in the fuel used in EU harbors from 2010. EU legislation combined with national normative resulted in the introduction of a limit of Sulphur content in maritime gasoil equal to 0.2% (2% before) from 2002 and 0.1% from 2010 while for fuel oil some limits occur only from 2008 (maximum Sulphur content of 1.5 % in harbor) and from 2010, 2% in domestic waters and 1% in harbors. For inland waterways, which include the navigation on the Po river and ferry-boats in the Venice lagoon, the same legislation is applied. Moreover, since January 2020, IMO introduced a limit of Sulphur content in marine fuel oil equal to 0.5% (previously equal to 3.5%) in IMO jurisdiction areas (except in ECAS areas, which have a stricter Sulphur content limit, equal to 0.1%). For international navigation 3% of Sulphur content in fuel oil has been assumed for the whole time series. Fuel oil accounts for about 98% of total international fuel consumption throughout the time series.

The composition of the fleet of gasoline fueled recreational craft distinguished in two strokes and four strokes engine distribution is provided by the industrial category association (UCINA, several years); the trend of the average emission factors considers the switch from two strokes to four strokes engines of the national fleet due to the introduction in the market of new models. In 2000, the composition of the fleet was 90% two-stroke engines equipped and 10% four-stroke while in the last year four-stroke engines are about 56 % of the fleet. The fuel split between national and international fuel use in maritime transportation is then supplied to the Ministry of Economic Development to be included in the official international submission of energy statistics to the IEA in the framework of the Joint Questionnaire OECD/EUROSTAT/IEA compilation together with other energy data. A discrepancy with the international bunkers reported to the IEA still remains, especially for the nineties, because the time series of the energy statistics to the IEA are not updated. PCB, HCB and Dioxins emissions are estimated with Tier1 emission factors available in the 2023 EMEP/EEA Guidebook (EMEP/EEA, 2023).

3.7.3 Time series and key categories

In Table 3.32 the list of key categories by pollutant identified for navigation in 2023, 1990 and at trend assessment is reported. Navigation is, in 2023, key category for many pollutants: SO_X, NO_X, PM10, PM2.5, BC; furthermore, it is a key driver of the SO_X, NO_X and BC trend.

Table 3.32 List of key categories for pollutant in navigation in 2023, 1990 and in the trend

	Key categories in 2023	Key categories in 1990	Key categories in trend
SO_x	1A3dii	1A3dii	1A3dii
NO_x	1A3dii	1A3dii	1A3dii
PM10	1A3dii	1A3dii	
PM2.5	1A3dii	1A3dii	
BC	1A3dii		1A3dii

Source: ISPRA elaborations

Estimates of fuel consumption for domestic use, in the national harbors or for travel within two Italian destinations, and bunker fuels used for international travels are reported in Table 3.33. An upward trend in emission levels is observed from 1990 to 2000, explained by the increasing number of ship movements. Nevertheless, the operational improvements in harbor activities and a reduction in ship domestic movements inverted the tendency in the last years.

Table 3.33 Marine fuel consumptions in domestic navigation and international bunkers (Gg) and pollutants emissions from domestic navigation (Gg)

Consumptions and Emissions for NFR Subsector 1.A.3.d	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Gasoline for recreational craft (Gg)	182	210	213	199	169	90	86	84	67	64
Diesel oil for inland waterways (Gg)	20	23	83	77	62	54	19	22	21	22
Fuels used in domestic cruise navigation (Gg)	778	706	811	740	725	525	667	511	571	604
Fuel in harbors (dom+int ships) (Gg)	748	693	818	759	844	733	1,054	807	903	954
Fuel in international Bunkers (Gg)	1,348	1,241	1,214	2,095	2,562	1,563	1,321	1,774	1,571	1,426
NO_x (Gg)	95.55	87.97	105.16	97.15	100.30	78.33	102.11	78.89	87.83	83.17
NMVOC (Gg)	46.11	52.42	50.47	43.53	32.50	16.45	15.09	13.25	9.53	8.78
SO_x (Gg)	77.94	70.31	81.53	49.73	30.99	22.46	11.34	7.16	9.39	8.04
PM2.5 (Gg)	9.30	8.83	9.89	9.14	8.77	6.01	8.34	6.36	6.81	6.43
PM10 (Gg)	9.33	8.86	9.93	9.17	8.80	6.04	8.34	6.36	6.82	6.43
BC (Gg)	1.33	1.25	1.56	1.44	1.42	1.10	1.82	1.60	1.58	1.61
CO (Gg)	102.27	115.57	125.46	123.43	110.69	60.20	55.70	51.07	41.91	40.14

3.7.4 QA/QC and Uncertainty

Basic data to estimate emissions are reconstructed starting from information on ship movements and fleet composition coming from different sources. Data collected in the framework of the national study from the local port authorities, carried out in 2009 (TECHNE, 2009), were compared with the official statistics supplied by ISTAT, which are collected from maritime operators with a yearly survey and communicated at international level to EUROSTAT. Differences and problems were analyzed in detail and solved together with ISTAT experts. Different sources of data are usually used and compared during the compilation of the annual inventory. Besides, time series resulting from the recalculation have been presented to the national experts in the framework of an ad hoc working group on air emissions inventory. The group is chaired by ISPRA and includes participants from the local authorities responsible for the preparation of local inventories, sectoral experts, the Ministry of Environment, Land and Sea, and air quality model experts. Top-down and bottom-up approaches have been compared with the aim of identifying the potential problems and future improvements to be addressed. There is also an ongoing collaboration and data exchange with regional environmental agencies on this issue.

3.7.5 Recalculations

Recalculations, respect to the previous submission occurred. ISTAT reviewed the number of ships arriving in Italian ports in 2022; therefore, emissions have been updated accordingly.

3.7.6 Planned improvements

Further improvements will include a verification of activity data on ship movements with ISTAT, the National Institute of Statistics.

3.8 PIPELINE COMPRESSORS (NFR SUBSECTOR 1.A.3.E)

Pipeline compressors category (1.A.3e) includes all emissions from fuels delivered to the transportation by pipelines and storage of natural gas. Relevant pollutant emissions typical of a combustion process, such as SO_X, NO_X, CO and PM emissions, derive from this category. This category is not a key category.

Emissions from pipeline compressors are estimated based on natural gas fuel consumption used for the compressors and the relevant emission factors. The amount of fuel consumption is estimated on data supplied for the whole time series by the national operators of natural gas distribution (SNAM and STOGIT) and refers to the fuel consumption for gas storage and transportation; this consumption is part of the fuel consumption reported in the national energy balance in the consumption and losses sheet. Emission factors are those reported in the EMEP/EEA Guidebook for gas turbines (EMEP/CORINAIR, 2007). Emissions communicated by the national operators in their environmental reports are also considered to estimate air pollutants, especially SO_X, NO_X, CO and PM10.

Regarding QA/QC, fuel consumption reported by the national operators for this activity is compared with the amount of natural gas internal consumption and losses reported in the energy balance as well as with energy consumption data provided by the operators to the emission trading scheme.

Starting from the length of pipelines, the average energy consumption by kilometer is calculated and used for verification of data collected by the operators. Energy consumptions and emissions by kilometer calculated on the basis of data supplied by SNAM, which is the main national operator, are used to estimate the figures for the other operators when their annual data are not available.

In Table 3.34, nitrogen oxides, non-methane volatile organic compounds, Sulphur oxides, particulate and carbon monoxide emissions (Gg) are reported.

Table 3.34 Emissions from pipeline compressors (Gg)

Emissions for NFR Subsector 1.A.3.e	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
NO_x	2.89	4.18	2.96	2.37	1.71	0.36	0.38	0.57	0.56	0.51
NMVOC	0.02	0.03	0.04	0.04	0.05	0.02	0.03	0.04	0.04	0.04
SO_x	0.006	0.009	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005
PM10	0.02	0.03	0.05	0.03	0.03	0.02	0.02	0.02	0.03	0.03
CO	1.26	1.38	1.03	0.60	0.61	0.23	0.16	0.26	0.30	0.33

Source: ISPRA elaborations

3.9 CIVIL SECTOR: SMALL COMBUSTION AND OFF-ROAD VEHICLES (NFR SUBSECTOR 1.A.4 - 1.A.5)

3.9.1 Overview

Emissions from energy use in the civil sector cover combustion in small-scale combustion units, with thermal capacity < 50 MWth, and off road vehicles in the commercial, residential and agriculture sectors.

The emissions refer to the following categories:

- 1 A 4 a i Commercial / Institutional: Stationary
- 1 A 4 a ii Commercial / Institutional: Mobile
- 1 A 4 b i Residential: Stationary plants
- 1 A 4 b ii Residential: Household and gardening (mobile)
- 1 A 4 c i Agriculture/Forestry/Fishing: Stationary
- 1 A 4 c ii Agriculture/Forestry/Fishing: Off-road Vehicles and Other Machinery
- 1A 4 c iii Agriculture/Forestry/Fishing: National Fishing
- 1 A 5 a Other, Stationary (including military)
- 1 A 5 b Other, Mobile (Including military, land based and recreational boats)

In Table 3.35 the list of categories for small combustion and off-road vehicles identified as key categories by pollutant for 2023, 1990 and in the trend is reported.

Table 3.35 List of key categories by pollutant in the civil sector in 2023, 1990 and trend

	Key categories in 2023			Key categories in 1990		Key categories in trend		
SO_x	1 A 4 b i	1 A 4 a i		1 A 4 b i		1 A 4 a i		
NO_x	1 A 4 b i	1 A 4 a i	1 A 4 c ii	1 A 4 c ii		1 A 4 a i	1 A 4 b i	1 A 4 c i
NMVOC	1 A 4 b i	1 A 4 a i		1 A 4 b i	1 A 4 c ii	1 A 4 b i	1 A 4 a i	1 A 4 c ii
CO	1 A 4 b i			1 A 4 b i	1 A 4 c ii	1 A 4 b i		
PM10	1 A 4 b i			1 A 4 b i	1 A 4 c ii	1 A 4 b i	1 A 4 c ii	
PM2.5	1 A 4 b i			1 A 4 b i	1 A 4 c ii	1 A 4 b i	1 A 4 c ii	
BC	1 A 4 b i			1 A 4 c ii	1 A 4 b i	1 A 4 b i	1 A 4 c ii	
Cd	1 A 4 b i			1 A 4 b i	1 A 4 a i			
Hg	1 A 4 b i	1 A 4 a i						
PAH	1 A 4 b i			1 A 4 b i		1 A 4 b i		
DIOX	1 A 4 b i			1 A 4 a i	1 A 4 b i	1 A 4 b i	1 A 4 a i	
HCB	1 A 4 b i	1 A 4 a i				1 A 4 a i	1 A 4 b i	
PCB	1 A 4 b i					1 A 4 b i		

3.9.2 Activity data

The Commercial / Institutional emissions arise from the energy used in the institutional, service and commercial buildings, mainly for heating. Additionally, this category includes all emissions due to waste used in electricity generation as well as biogas recovered in landfills and wastewater treatment plants. In the residential sector the emissions arise from the energy used in residential buildings, mainly for heating and the sector includes emissions from household and gardening machinery. The Agriculture/ Forestry/ Fishing sector includes all emissions due to the fuel, including biogas from biodigestors, used in agriculture, mainly to produce mechanical energy, the fuel use in fishing and for machinery used in the forestry sector. Emissions from military aircraft and naval vessels are reported under 1A.5.b Mobile.

Emissions from 1.A.4.a ii are reported as IE, included elsewhere, because they refer to road transport emissions of institutional and commercial vehicles. These emissions are estimated, and reported in 1.A.3.b, with a model (COPERT 5) which consider the vehicle fleet subdivided by technology and fuel and not by user. Emissions from 1.A.5.a are also reported as IE because they refer to stationary combustion in commercial and residential of military which are included and reported in 1.A.4.a i and 1.A.4.b i; also in this case the relevant energy statistics are not available by user. The estimation procedure follows that of the basic combustion data sheet. Emissions are estimated from the energy consumption data that are reported in the national energy balance (MASE, several years [a]) and separating energy consumption between commercial/institutional, residential, agriculture and fishing, according to the information available in the Joint Questionnaire OECD/IEA/EUROSTAT prepared by the Ministry of Environment and officially sent to the international organizations. Emissions from 1.A.4.b Residential and 1.A.4.c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. With the previous submission, a review process of the national energy balance was initiated with Eurostat. In a first step, experts responsible for the National Energy Balance implemented methodological changes for 2022 and subsequently applied these changes to 2021 to make it consistent. The review process, carried out in agreement with the relevant international institutions, regards definitions of "main activity producer" and "autoproducer" and the consequent adoption by Italy of these definitions in place of those previously used and linked to Italian legislation. This change in methodology has caused a fairly evident break in the series for some fuels and it is necessary further work to improve the time series consistency. The collaboration with energy balance experts is now continuing through systematic comparisons of fuel consumption using data from the ETS.

The time series of fuel consumption for the civil sector is reported in Table 3.36.

Table 3.36 Time series of fuel consumption for the civil sector.

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
	TJ									
1 A 4 a i Commercial / Institutional: Stationary plants	206,427	247,440	306,088	419,507	488,708	400,595	402,497	370,464	326,802	352,386
1 A 4 b i Residential: Stationary plants	1,002,131	1,003,620	1,036,801	1,172,245	1,222,522	1,078,829	997,306	1,091,916	955,359	857,237
1 A 4 b ii Residential: Household and gardening (mobile)	466	571	374	154	66	57	35	29	22	15
1 A 4 c i Agriculture/Forestry/ Fishing: Stationary	9,688	9,584	8,234	10,599	10,980	19,645	20,852	29,672	30,834	29,587
1 A 4 c ii Agriculture/Forestry/ Fishing: Off-road Vehicles and Other Machinery	96,536	101,928	94,668	95,869	84,461	81,263	84,000	82,878	78,924	75,810
1A 4 c iii Agriculture/Forestry/ Fishing: National Fishing	8,413	9,651	8,584	10,464	7,731	6,194	6,688	6,233	5,937	5,704
1 A 5 b Other, Mobile (Including military, land based and recreational boats)	14,840	20,814	11,595	16,947	9,001	6,388	8,733	4,385	7,139	5,084

3.9.3 Methodological issues

The Tier 2 methodology is applied to the whole category. Emissions are estimated for each fuel and category at detailed level and country specific emission factors are used for the key fuel and categories drivers of total emission trend. More in detail, 1.A.4.a i, is key category in 2023 for SO_X, NO_X, NMVOC, Hg and HCB emissions as well as for cadmium and Dioxin in 1990, and SO_X, NOx, NMVOC, HCB and dioxins in trend analysis. Most of these pollutants are due prevalently to emissions from waste incineration with energy recovery (about 99% for HCB, and more than 90% for PCB and HMs, except for Hg (78%) and Ni (84%)). Emissions from waste combustion in incinerator with energy recovery have been calculated with a Tier 3 methodology from the database of incinerator plants which includes plant specific emission factors on the basis of their technology and measurements data (ENEA-federAmbiente, 2012). The methodology used to estimate emissions from incinerators is reported in the relevant paragraph on waste incineration in the waste sector, and in particular EFs are reported in Table 7.4. Up to 2009 emission factors have been estimated on the basis of a study conducted by ENEA (De Stefanis P., 1999), based on emission data from a large sample of Italian incinerators (FEDERAMBIENTE, 1998; AMA-Comune di Roma, 1996), legal thresholds (Ministerial Decree 19 November 1997, n. 503 of the Ministry of Environment; Ministerial Decree 12 July 1990) and expert judgements. Waste management with incinerators is a commercial activity with recovery of the energy auto-produced and emissions from these plants are allocated in the commercial / institutional category because of the final use of heat and electricity production. In fact, until the early 2000s, electricity and heat produced by incinerators have been prevalently used to satisfy the energy demand from connected activities: heating of buildings, domestic hot water and electricity for offices. This is still true in particular for industrial and hospital incinerators, meanwhile municipal solid waste incinerators have increased the amount of energy provided to the grid from the early 2000s until now, although only a small percentage of energy produced goes to the electricity grid (around 10%); the energy recovered by these plants is mainly used for district heating of commercial buildings or used to satisfy the internal energy demand of the plants. Since 2010, emission factors for urban waste incinerators have been updated on the basis of data provided by plants (ENEA-federAmbiente, 2012; De Stefanis P., 2012) concerning the annual stack flow, the amount of waste burned and the average concentrations of the pollutants at the stack and taking in account the abatement technologies in place. As the emission factors are considerably lower than the old ones due to the application of very efficient abatement systems it was necessary to apply a linear smoothing methodology assuming a progressive application of the abatement systems between 2005 and 2010. In a similar way, emission factors for industrial waste incinerators have been updated from 2010 onwards on the basis of the 2019 EMEP/EEA Guidebook. Similarly, municipal waste smoothing has been applied between 2005 and 2010 supposing a linear application of the abatement systems. The other fuels driving emissions from this category are wood combustion, especially for NMVOC and PM, and natural gas for NO_X while the trend of SO_X is driven by the decrease both of liquid fuel, as gasoil, fuel oil and kerosene, consumptions and their sulphur content which is also decreased according to European Union and national legislation. For what concerns wood combustion, the NMVOC average emission factor, as well as all the other pollutants, takes into account the different technologies used and is calculated on the basis of country specific emission factors and the ranges reported in the 2019 EMEP/EEA Guidebook; see paragraph 3.9.3.2 for details on methodology and emission factors. For natural gas and NO_X emissions a Tier 2 methodology is used and country specific emission factors, as described in the following paragraph 3.9.3.1. For the other fuels the default emission factors of EMEP/CORINAIR 2007 Guidebook have been used but according to the 2023 review process, the update of EFs started with COVNM emissions on the basis of 2019 EMEP/EEA Gidebook continuing in the following years with NOx and PM.. For gasoil, biogas and gasoline different emission factors are used for stationary engines and boilers. Concerning the other pollutants, PM2.5 emissions from wood account for around 81% of the total 1.A.4.a i category; the other main fuel used for this category is biogas from landfills and wastewater treatment energy recovery, which account for around 9% of PM2.5 emissions of this category; an emission factor equal to 10 g/GJ is used. For NO_X, in addition to waste fuel, see methodology in the waste chapter and in particular emission factors reported in Table 7.4, and natural gas, as described in the following paragraph 3.9.3.1, the other main fuel driving emission estimates is biogas from landfills and wastewater treatment energy recovery, accounting for 42% of NO_X emissions of this category in 2023, but for which no guidance is provided in the Guidebook. An emission factor equal to 1 kg/GJ has been used taking into account that the gas is burnt in stationary engines. NO_X emissions from waste and biogas account for more than 70% of total NO_X category emissions. HM and POP emissions from the sector are prevalently from waste incineration, estimated with country specific EFs, at technology level, and from wood combustion estimated also with country specific EFs in the range of 2019 EMEP/EEA Guidebook values.

For 1.A.4.b i, the category is key category in 2023 for SO_X, NO_X, NMVOC, CO, PM10, PM2.5, BC, Cd, Hg, PAH, Dioxin, HCB and PCB emissions. More, in 1990 NOx, Hg, HCB and PCB are not key categories. At trend assessment NOx, NMVOC, CO, PM10, PM2.5, BC, PAH, dioxins, HCB and PCB are key categories. Most of these pollutants are due prevalently to emissions from wood combustion: between 98% and 100% for NH_3, CO, NMVOC, PM, BC, PAH, dioxins, HMs (except Hg with 48%, Cd with 93%, Ni with 95% and As with 82%), HCB and PCB emissions, 73% for SO_X and 48% of the total for NO_X for which a Tier 2 is applied. Methodology and emission factors are described in paragraph 3.9.3.2. For SO_X country specific and updated emission factors are used for wood, gasoil, residual oil, natural gas and LPG calculated on the basis of the maximum content of sulphur in these fuels; emissions from these fuels account for about 99.9% of SO_X category emissions. A country specific methodology has been developed and applied to estimate NO_X emissions from gas powered plants and all emissions from wood combustion. About 46% of the total NO_X emissions are due to the combustion of natural gas; methodology and country specific emission factors are described in the following paragraph 3.9.3.1. Biomass combustion accounts for around 48% of the total of NO_X emissions and methodology and country specific emission factors are also available in paragraph 3.9.3.2. All these fuels cover more than 90% of total category emissions in 2023. According to the previous review processes, an update of EFs occurs for NO_X, NMVOC and PM2.5 since 2000.

For 1.A.4bii, 1.A.4cii, 1.A.4ciii and 1.A.5b emission estimates are calculated taking into account the relevant changes in emission factors along the time series due to the introduction of the relevant European Union Directives for off-road engines. Regarding mobile machinery used in agriculture, forestry and household, these sectors were not governed by any legislation until Directive 97/68/EC (EC, 1997 [a]), which provides for a reduction in NO_X limits from 1st January 1999, and Directive 2004/26/EC (EC, 2004) which provide further reduction stages with substantial effects from 2011, with a following decreasing trend particularly in recent years. For engines with lower power as those used in forestry, household and gardening, the European Directives introduce emissions limits only starting from 2019 and 2021 so they have not had effect up to now. Moreover, for the categories 1.A.4.bii, 1.A.4.cii and 1.A.4.ciii, Pb emissions from 2002 are reported as 'NA', because of the introduction of unleaded liquid fuels in the market in 2002. In particular heavy metals contents values derive from the analysis about the physical - chemical characterization of fossil fuels used in Italy (Innovhub, Fuel Experimental Station, several years). According to the review (EEA, 2019), PCB, HCB and Dioxins emissions have been estimated and included in the inventory for 1.A.4.ciii category with the emission factors of Tier1 available in the 2019 EMEP/EEA Guidebook.

3.9.3.1 NO_X emissions from gas powered plants in the civil sector

A national methodology has been developed and applied to estimate NO_X emissions from gas powered plants in the civil sector, according to the EMEP/EEA Guidebook (EMEP/EEA, 2019). On the basis of the information and data reported in available national studies for the year 2003, a distribution of heating plants in the domestic sector by technology and typology has been assessed for that year together with their specific emissions factors. Data related to heating plants, both commercial and residential, have been supplied for 2003 by a national energy research institute (CESI, 2005). In this study, for the residential sector, the sharing of single and multifamily houses plants by technology and a quantitative estimation of the relevant gas powered ones are reported, including their related NO_X emission factors. Domestic final consumption by type of plant, single or multifamily plants, has been estimated on the basis of data supplied by ENEA on their distribution (ENEA, several years). Data reported by ASSOTERMICA (ASSOTERMICA, several years) on the number of heating plants sold are used for the years after 2003 to update information related to the technologies. A linear regression, for the period 1995-2003, has been applied, while for the period 1990-1994, the technology with the highest emission factor has been assumed to be operating. In Table 3.37 the time series of NO_X average emission factors for the relevant categories is reported.

Table 3.37 Time series of NO_X emissions factor for the civil sector.

NO_x EFs	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
						g/Gj				
1 A 4 a i Commercial / Institutional: Stationary	50.0	48.5	40.2	35.2	32.4	30.3	28.5	28.1	27.7	27.3
1 A 4 b i Residential: Stationary plants	50.0	48.2	38.6	32.4	31.3	30.5	29.3	29.3	29.2	29.1

3.9.3.2 Emissions from wood combustion in the civil sector

A national methodology has been developed and applied to estimate emissions from wood combustion in the civil sector, according to the TIER 2 methodology reported in the EMEP/EEA Guidebook (EMEP/EEA, 2019). In the past years, several surveys have been carried out to estimate national wood consumption in the domestic heating and the related technologies used. In the estimation process, three surveys have been taken into account: the first survey (Gerardi and Perrella, 2001) has evaluated the technologies for wood combustion used in Italy for the year 1999, the second survey (ARPA, 2007) was related to the year 2006, while the third survey (SCENARI/ISPRA, 2013) was related to the year 2012. For 2015 and 2019 information on the use of pellet, as available in the national energy balance, and on the relevant technologies, as provided by the industrial association, has been used to take in account the increase of pellet used for heating; the update has been developed taking into account also the results of the surveys on wood consumption and combustion technologies carried out by ISPRA (SCENARI/ISPRA, 2013) and by ISTAT (ISTAT, 2014). Starting from 2014, the ISTAT survey has been systematized (2021 survey completed, 2024 survey in progress) and the results used in the creation of the National Energy Balance. The technologies assessed by the abovementioned surveys and the distribution of fuel combustion by technologies are reported in Table 3.38.

Table 3.38 Distribution of wood combustion by technologies

Distribution of wood combustion by technologies	1999	2006	2012	2015	2019	2020-2021	2022-2023
				%			
Fireplaces	51.3	44.7	51.2	49.0	40.3	39.7	40.8
Stoves	28.4	27.6	22.9	21.0	18.4	17.9	18.3
Advanced fireplaces	15.4	20.2	15.8	15.0	19.7	19.5	19.0
Pellet stoves	0	3.1	4.0	9.0	13.6	15.1	14.0
Advanced stoves	4.8	4.4	6.0	6.0	7.9	7.8	8.0

Average emission factors for 1999, 2006, 2012, 2015, 2019, 2020-2021 and 2022-2023 have been estimated at national level taking into account the technology distributions; for 1990 only old technologies (fireplaces and stoves) have been considered and linear regressions have been applied to reconstruct the time series from 1990 to 2006. For the years till 2011, emission factors from 2006 have been used in absence of further available information. The distribution of combustion technologies is updated, starting from this year, on an annual or biennial basis based on the sales data of the equipment by type. For NMVOC, PAH, PM10 and PM2.5 emission factors the results of the experimental study funded by the Ministry of Environment and conducted by the research institute 'Stazione Sperimentale dei Combustibili' now Innovhub (SSC, 2012; INNOVHUB, 2021) have been used. This study measured and compared NO_X, CO, NMVOC, SO_X, TSP, PM10, PM2.5, PAH and Dioxin emissions for the combustion of different wood typically used in Italy as beech, hornbeam, oak, locust and spruce-fir, in open and closed fireplaces, traditional and innovative stoves and pellet stoves. Emissions from certificated and not certificated pellets have been also measured and compared. In general, measured emission factors result in the ranges supplied by the EMEP/EEA Guidebook but for some pollutants and technologies results are sensibly different. In particular NMVOC emissions for all the technologies are close or lower to the minimum value of the range reported in the Guidebook, as well as PM emissions with the exception of emissions from pellet stoves which are higher than the values suggested in the case of the use of not certificated pellet. For these pollutants the minimum values of the range in the Guidebook have been used when appropriate. For that concern PAH, measured emissions from open fireplaces are much lower than the minimum value of the range in the Guidebook while those from the advanced stoves are close to the superior values of the range for all the PAH compounds. In this case, for open fireplaces, experimental values have been used while for the other technologies the minimum or maximum values of the range in the Guidebook have been used as appropriate. For the other pollutants where differences with the values suggested by the Guidebook are not sensible, a more in-depth analysis will be conducted with the aim to update the emission factors used if needed. During 2020, a new experimental study funded by the Ministry of Environment and managed by ISPRA has been completed (INNOVHUB, 2021). This study regards the analysis on advanced appliances burning solid biomass (beech, fir and hornbeam, pellet A1, pellet A2). The pollutants that have been monitored are: CO, NO_X, SO_2, PM, PAH. The study also contains an interesting comparison between standard methodology and the BeReal method. In Table 3.39 emission factors used for the Italian inventory are reported.

Table 3.39 Emission factors for wood combustion

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
NO_x	50	55	59	61	61	61	66	66	66	66
CO	6000	5791	5591	5427	5395	5010	4564	4564	4609	4609
NMVOC	762	715	672	643	638	597	526	526	533	533
SO_2	10	11	12	13	13	13	14	14	14	14
NH_3	9	7	6	6	6	6	5	5	5	5
PM10	507	465	428	409	406	392	348	348	352	352
PM2.5	503	461	424	405	402	388	344	344	348	348
BC	40	37	35	34	34	33	31	31	31	31
PAH	0.25	0.24	0.23	0.23	0.22	0.21	0.19	0.19	0.19	0.19
Dioxin (µg/GJ)	0.48	0.47	0.45	0.44	0.43	0.40	0.36	0.36	0.37	0.37
PCB	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006	0.00006
HCB	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
As	0.001	0.001	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Cd	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cr	0.001	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Cu	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hg	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Ni	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Pb	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Se	0.001	0.001	0.001	0.001	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Zn	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
B(a)P	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06
B(b)F	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07
B(k)F	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
IND	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04

Finally, ISTAT – the national statistical institute - following different requests made by various subjects interested in the data, designed and implemented a periodic campaign on "Household energy consumption" including biomass consumption. The results of this survey are the basis of the wood consumption data reported in the energy balance. In 2014 the National Institute of Statistics (ISTAT) carried out a survey, funded by the Ministry of Economic Development (MASE), on the final energy consumption of households for residential heating which include the fuel consumption of solid biomass, as wood and pellets (ISTAT, 2014). In this regard the survey resulted in an official statistic for 2012 and 2013 of wood and pellet fuel consumption at national and regional level including the information on the relevant equipment. The resulting figure for 2013 doubled the value reported in the National Energy Balance for previous years which asked for the need to update the whole time series. An ad hoc working group has been established, involving ISPRA, MASE and the energy management system national operator (GSE), to reconstruct the complete time series of wood and pellet fuel consumption which has been recalculated and officially submitted to Eurostat in June 2015. The methodology to recalculate consumption figures has taken into account the amount of wood harvested for energy purposes, the amount of wood biomass from pruning, import and export official statistics to estimate total wood consumption. A model to estimate the annual amount of wood for heating has been developed on the basis of the annual energy total biomass demand of households estimated considering the degree days time series, the number of households, the energy efficiency of equipment and fuel consumption statistics for the other fuels. As a consequence, time series for residential heating has been completely recalculated affecting the relevant pollutants and resulting in important recalculations at national total levels.

3.9.4 Time series and key categories

The time series of emissions for the civil sector shows an increasing trend for several pollutants, except for SO_X and NO_X, due to a gradual shift from diesel fuel to gas, concerning SO_X, and to a replacement of classic boilers with those with low NO_x emission. Many other pollutants have a growing trend, as a consequence of the increase of wood combustion. In particular the pollutants which are more affected by the increase of wood biomass in this category according to data available in the National Energy Balance are PM, PAH, NMVOC and CO. In particular for 1.A.4.c i the increasing trend of PAH in the last years is due to the increase of wood combustion for this category. More in detail the decrease in SO_X emissions is the combination of the switch of fuel from gasoil and fuel oil to natural gas and LPG and the reduction in the average sulphur content of liquid fuels. The SO_X emission factors for 1990 and 2023 by fuels are shown in the following Table 3.40.

Table 3.40 SO_x emission factors by fuel

FUEL – SO_x EFs(kg/Gj)	1990	2023
steam coal	0.646	0.646
coke oven coke	0.682	0.682
wood and similar	0.010	0.014
municipal waste	0.069	0.048

FUEL – SO_x EFs(kg/Gj)	1990	2023
Biodiesel	0.047	0.047
residual oil	1.462	0.146
gas oil	0.140	0.047
Kerosene	0.018	0.018
natural gas	0.0003	0.0003
Biogas	-	-
LPG	0.0022	0.0022
gas works gas	0.011	0.011
motor gasoline	0.023	0.023

Time series of emissions is reported in Table 3.41.

Table 3.41 Time series of emissions in civil sector: small combustion and off-road vehicles

		1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
SO_x (Gg)	1A4	96.5	42.7	26.4	22.8	12.1	10.3	9.8	10.1	9.2	9.1
	1A5	1.2	0.8	0.2	0.2	0.1	0.1	0.2	0.1	0.2	0.1
NO_x (Gg)	1A4	175.0	187.2	171.8	163.0	144.0	127.0	113.9	115.2	105.8	101.1
	1A5	11.2	12.0	7.2	13.5	6.1	3.3	3.5	1.9	2.8	1.9
CO (Gg)	1A4	1093.2	1088.8	1028.0	997.4	1716.1	1440.7	1244.9	1395.3	1279.7	1241.8
	1A5	65.1	79.0	45.5	54.5	17.3	16.5	24.9	12.0	20.3	14.6
PM10 (Gg)	1A4	84.6	89.8	84.6	80.3	129.1	110.2	91.6	102.7	94.1	91.4
	1A5	1.3	1.5	0.9	1.6	0.8	0.5	0.6	0.3	0.4	0.3
PM2.5 (Gg)	1A4	83.8	89.0	83.9	79.6	127.8	109.0	90.5	101.5	92.9	90.3
	1A5	1.3	1.5	0.9	1.6	0.8	0.5	0.6	0.3	0.4	0.3
BC (Gg)	1A4	14.9	16.1	14.6	12.4	13.7	11.0	9.0	9.8	8.8	8.5
	1A5	0.7	0.8	0.5	0.9	0.5	0.2	0.3	0.1	0.2	0.2
Pb (Mg)	1A4	82.0	34.3	24.6	46.3	16.5	15.1	13.6	14.7	13.7	13.7
	1A5	16.3	4.2	1.2	0.0	NA	0.1	0.2	0.1	0.1	0.0
Cd (Mg)	1A4	1.5	1.2	1.7	2.6	0.7	0.6	0.5	0.5	0.5	0.5
	1A5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hg (Mg)	1A4	0.6	0.7	1.0	2.0	0.5	0.5	0.5	0.5	0.4	0.4
	1A5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PAH (Mg)	1A4	32.1	35.4	35.9	39.1	67.4	56.1	48.7	55.0	50.5	49.1
	1A5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

		1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
HCB (Kg)	1A4	2.6	3.6	7.0	7.1	5.1	3.8	4.0	4.1	3.6	3.6
	1A5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB (Kg)	1A4	14.9	18.3	25.7	36.3	22.0	19.0	18.5	20.4	18.4	18.1
	1A5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

3.9.5 QA/QC and Uncertainty

Basic data used in the estimation process are reported by the Ministry of Environment in the National Energy Balance (MASE, several years (a)) and by TERNA (National Independent System Operator), concerning the waste used to generate electricity. The energy data used to estimate emissions have different levels of accuracy:

- the overall sum of residential and institutional/service/commercial energy consumption is quite reliable and their uncertainty is comparable with data reported in the BEN; the amount of fuels used is periodically reported by main suppliers;
- the energy consumption for agriculture and fisheries is reported in energy statistics; data are quite reliable as they have special taxation regimes and they are accounted for separately;
- the energy use for military and off roads is reported in official statistics, but models are applied to estimate the energy use at a more disaggregated level.

3.9.6 Recalculation

Some recalculations affected 1A4 category in this submission due to the update of incineration with energy recovery. Major differences have been found in 2022 because of the update of activity data resulting in -16% for HCB and -10% for PCB emissions, for other pollutants recalculations are less than ±0.5%. Minor recalculations have occurred throughout the time series because of the update of historical data of a single plant in the years 2002 and 2006-2010.

More, the reconstruction of old info about another plant led to recalculations on dioxins emission in the years 1995-200, 2002, 2005-2010 with differences from -3% in 1995 to -43% in 2007, year for which a bug was fixed.

3.9.7 Planned improvements

The updating of average emission factors will continue in future submissions on the basis of the surveys on wood consumption and combustion technologies planned by ISTAT on fuel consumptions as well as from the results of an emission factor measurements campaign realized in Italy (ALTROCONSUMO, 2018), and the measurements campaign on advanced stoves completed by Innovhub. An in-depth analysis of emission factors resulting from this experimental studies and their comparison with the values suggested by the last version of the EMEP/EEA Guidebook (EMEP/EEA, 2023) will be carried out and emission factors will be updated as needed.

3.10 FUGITIVE EMISSIONS (NFR SUBSECTOR 1.B)

3.10.1 Overview

Fugitive emissions arise during the stages of fuel production, from extraction of fossil fuels to their final use. Emissions are mainly due to leaks or other irregular releases of gases from the production and transformation of solid fuels, the production of oil and gas, the transmission and distribution of gas and from oil refining, as well as from geothermal energy production. In Table 3.42 the list of categories for fugitive emissions identified as key categories by pollutant for 2023, 1990 and in the trend is reported.

Table 3.42 List of key categories by pollutant in the civil sector in 2023, 1990 and trend

	Key categories in 2023	Key categories in 1990	Key categories in trend
SO_X	1 B 2 a iv	1 B 2 a iv	1 B 2 a iv, 1 B 2 c
NMVOC		1 B 2 a v	1 B 2 a v
NH_3			1 B 2 d
Hg		1 B 2 d	1 B 2 d

3.10.2 Methodological issues

In the following methodological issues including activity data and emission factors used are reported for each category and pollutant estimated in this sub sector.

Coal mining and handling (1B1a)

NMVOC emissions from coal mining have been estimated on the basis of activity data published on the national energy balance (MASE, several years [a]) which report the amount of coal production and emission factors provided by the EMEP/EEA Guidebook (EMEP/EEA, 2016). PM emissions from storage of solid fuels have been estimated and included in this category. Activity data is the annual consumption of solid fuels published on the national energy balance (MASE, several years [a]) and emission factors are from the US EPA Guidebook.

Solid fuel transformation (1B1b)

NMVOC emissions from coke production have been estimated on the basis of activity data published in the national energy balance (MASE, several years [a]) and country specific emission factors calculated taking in account the information provided by the relevant operators in the framework of the EPRTR registry and the ETS. NO_X, SO_X and NH_3 emissions from coke production are estimated on the basis of data communicated by the national plants in the framework of the EPRTR and are reported under 1.A.1 c category. NH_3 emissions have been estimated on the basis of data communicated by the operators for the EPRTR registry from 2002. PAH emissions from coke production have been also estimated with emission factor from the 2019 EMEP/EEA Guidebook and allocated in 1.B.1b.

Oil exploration and production (1B2a i)

NMVOC emissions have been calculated according to activity data published on national energy balance (MASE, several years [a]), data by oil industry association (UNEM, several years), data and emission factors provided by the relevant operators.

Oil transport and storage and refining (1B2a iv)

Fugitive emissions from oil refining are estimated starting from the total crude oil losses as reported in the national energy balance (MASE, several years [a]) and occur prevalently from processes in refineries. This category is key for SO_X in 2023, in the base year and for the trend. Emissions in refineries have been estimated on the basis of activity data published in the national energy balance (MASE, several years [a]) or supplied by oil industry association (UNEM, several years) and operators especially in the framework of the European Emissions Trading Scheme (EU-ETS). Fugitive emissions in refineries are mainly due to catalytic cracking production processes, sulphur recovery plants, flaring and emissions by other production processes including transport of crude oil and oil products. These emissions are then distributed among the different processes on the basis of average emission factors agreed and verified with the association of industrial operators, Unione Energia per la Mobilità, and yearly updated, from 2000, on the basis of data supplied by the plants in the framework of the European Emissions Trading Scheme, Large Combustion Plant Directive and EPRTR. SO_X, NO_X and PM emissions communicated by the plants in the framework of Large Combustion Plants directive are assumed to refer to combustion and are reported under 1.A.1b while the difference with the totals, communicated to the EPRTR, are considered as fugitive emissions and reported in 1.B.2a iv. NMVOC are communicated by the operators for the EPRTR registry as a total and the amount to be reported as fugitive is calculated subtracting by the total emission estimates for combustion activities and reduced for the implementation of losses control technology especially for transportation and storage of liquid fuels. ETS data are used to integrate and check emission data provided. Moreover, fugitive emissions are also checked with the average emission factors provided by the relevant industrial association for each relevant process, as fluid catalytic cracking, sulphur recovery plant, and storage and handling of petroleum products. NH_3 emissions from refineries have been estimated on the basis of data communicated by the operators for the EPRTR registry and distributed between combustion and fugitive emissions according to the emission factors available in the 2016 EMEP/EEA Guidebook. Emissions from refineries of HM and POPs are all reported in 1.A.1b on the basis of data submitted in the PRTR framework at plant level; it is not possible at the moment distinguish combustion by fugitive emissions of HM and POPs.

Distribution of oil products (1B2a v)

This category is key for NMVOC in 1990 and for the trend. The category includes fugitive emissions from oil transport which have been calculated according to the amount of transported oil (MIT, several years) and emission factors published on the IPCC guidelines (IPCC, 2006). Most of the crude oil is imported in Italy by shipment and delivered at the refineries by pipelines as offshore national production of crude oil. The category includes also NMVOC fugitive emissions for gasoline distribution, storage and at service stations. Emission factors are estimated starting from the emissions communicated in the nineties by the operators and applying the implementation of the abatement technologies as regulated by the relevant European Union legislation. Emissions from distribution of gasoline have been reduced as a result of the application of DM 16th May 1996 (Ministerial Decree 16 May 1996), concerning the adoption of devices for the recovery of vapours and of the applications of measures on deposits of gasoline provided by the DM 21st January 2000 (Ministerial Decree 21 January 2000).

Flaring in refineries (1B2c)

This category is key for SO_x for the trend. For what concern emissions from flaring in refineries, the emission factors for SO_X, NO_X, NMVOC and CO have been provided by the relevant industrial association and are assumed constant since 1990 with the exception of SO_X that are yearly estimated on the basis of the amount of sulphur not recovered by the operators and flared. Activity data, in terms of gas flared, is from 2005 derived by the ETS data at plant level.

Fugitive emissions from geothermal production (1B2d)

According to the review process NH_3, Hg and other heavy metals from geothermal production have been estimated and included in the emission inventory in the 2018 submission with a Tier 2 methodology. Hg from this category is key category for the base year and the trend while NH_3 is key only for the trend. Emissions are monitored by the Regional relevant environmental agency, ARPAT, where all the geothermal fields are located. Activity data, geothermal energy production, are published in the national energy balance (MASE, several years [a]) while emission data resulting by the monitoring are issued by ARPAT and reported from 2000 on a yearly basis (ARPAT, several years). For earlier years emission factors of 2000 have been used.

3.10.2.1 Fugitive emissions from natural gas distribution (1.B.2b)

NMVOC fugitive emissions from the transport, storage and distributions (including housing) of natural gas (both in pipelines and in the distribution network) are calculated every year on the basis of fugitive natural gas emissions and the content of NMVOC in the gas distributed; NMVOC emissions due to transport and distribution are around 99% of the total. Emissions are calculated starting from methane emissions estimates, considering the annual average percentage of NMVOC in the natural gas distributed in Italy as in Table 3.43. The methodology and references are reported in detail in the NID (ISPRA, 2025[a]). CH_4, CO_2 and NMVOC emissions have been estimated on the basis of activity data published by industry, the national authority, and information collected annually by the Italian gas operators. Emission estimates take into account the information on: the amount of natural gas distributed supplied by the main national company (SNAM); length of pipelines, distinct by low, medium and high pressure and by type, cast iron, grey cast iron, steel or polyethylene pipelines as supplied by the national authority for the gas distribution (ARERA); natural gas losses reported in the national energy balance; methane emissions reported by operators, in their environmental reports (EDISON, SNAM, ENEL, Italgas). NMVOC and CO_2 emissions have been calculated considering CO_2 content in the leaked natural gas. Regarding exploration and production, an average emission factor, equal to 0.04 g/m^3 gas produced, has been estimated on the basis of emission data communicated by the relevant companies for some years and applied to the whole time series.

The average natural gas chemical composition has been calculated from the composition of natural gas produced and imported. Main parameters of mixed natural gas, as calorific value, molecular weight, and density have been calculated as well. Data on chemical composition and calorific value are supplied by the main national gas providers for domestic natural gas and for each country of origin.

The following table shows average data for national pipelines natural gas.

Table 3.43 Average composition for pipelines natural gas and main parameters

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
HCV (kcal/m^3)	9,156	9,193	9,215	9,261	9,325	9,303	9,340	9,377	9,428	9,438
NCV (kcal/m^3)	8,255	8,290	8,320	8,354	8,412	8,391	8,432	8,467	8,515	8,524
Molecular weight	17.03	17.19	17.37	17.45	17.46	17.34	17.33	17.48	17.56	17.56
Density (kg/Sm^3)	0.72	0.73	0.74	0.74	0.74	0.73	0.73	0.74	0.74	0.74
CH_4 (molar %)	94	93	92	92	92	93	93	92	91	91
NMVOC (molar %)	3	4	5	5	6	5	6	6	7	7
CO_2 (molar %)	0.22	0.20	0.18	0.49	0.75	0.70	0.88	0.91	0.83	0.74
Other no carbon gas (molar %)	2.03	2.34	2.76	2.24	1.48	1.32	0.70	0.91	0.94	1.00
CH_4 (weight %)	89	87	85	85	85	86	86	84	84	83
NMVOC (weight %)	7	9	10	11	11	10	11	12	13	13
CO_2 (weight %)	0.57	0.51	0.47	1.23	1.89	1.78	2.25	2.29	2.09	1.86
Other no carbon gas (weight %)	3.27	3.74	4.37	3.51	2.30	2.08	1.09	1.41	1.43	1.54

More in details, emissions are estimated separately for the different phases: transmission in primary pipelines and distribution in low, medium, and high-pressure network, losses in pumping stations and in reducing pressure stations (including venting and other accidental losses) with their relevant emission factors, considering also information regarding the length of the pipelines and their type.

Emissions from low pressure distribution also include the distribution of gas at industrial plants and in residential and commercial sector; data on gas distribution are only available at an aggregate level thus not allowing a separate reporting. In addition, emissions from the use of natural gas in housing are estimated and included. Emissions calculated are compared and balanced with emissions reported by the main distribution operators. Finally, the emission estimates for the different phases are summed and reported in the most appropriate category (transmission/distribution).

Table 3.44 provides the trend of natural gas distribution network length for each pipeline material and the average CH_4 emission factor.

Table 3.44 Length of low and medium pressure distribution network (km) and network emission factors for CH_4 and NMVOC

Material	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Steel and cast iron (km)	102,061	131,271	141,848	154,886	198,706	203,116	208,044	208,935	209,740	210,737
Grey cast iron (km)	24,164	22,784	21,314	15,080	4,658	2,398	2,061	2,060	2,060	1,965
Polyethylene (km)	775	8,150	12,550	31,530	49,663	56,943	59,854	61,325	61,441	61,881
Total (km)	127,000	162,205	175,712	201,496	253,027	262,457	269,959	272,320	273,241	274,583
CH_4 EF (kg/km)	1,958	1,417	1,228	1,000	703	540	350	333	278	234
NMVOC EF (kg/km)	162	140	144	127	94	65	44	47	43	37

3.10.3 Time series and key categories

The trend of fugitive emissions from solid fuels is related to the extraction of coal and lignite that in Italy is quite low. The decrease of NMVOC fugitive emissions from oil and natural gas is due to the reduction of losses for gas transportation and distribution, because of the gradual replacement of old grey cast iron pipelines with steel and polyethylene pipelines for low and medium pressure network as reported in the previous paragraph.

3.10.4 QA/QC and Uncertainty

Different data sources are used for fugitive emissions estimates: official statistics by Environmental Ministry (MASE, several years [a], [b]), by Transport of Infrastructure Ministry (MIT, several years); national authorities (ARERA, several years; ISTAT, several years [a]), gas operators (ENI, several years [a]; EDISON, several years; SNAM, several years), and industrial association for oil and gas (UP, several years).

CH_4 and NMVOC emissions from transmission and distribution of natural gas are verified considering emission factors reported in literature and detailed information supplied by the main operators (ENI, several years [b]; Riva, 1997).

3.10.5 Recalculation

Recalculations occured for NMVOC emissions in 2022 from liquid fuel distribution because of the update of activity data resulting in a variation equal to +1.9%.

3.10.6 Planned improvements

No further improvements are planned for this category.

4 IPPU - INDUSTRIAL PROCESSES (NFR SECTOR 2)

4.1 OVERVIEW OF THE SECTOR

Emission estimates in this category include emissions from all industrial processes and also by-products or fugitive emissions, which originate from these processes. Where emissions are released simultaneously from the production process and from combustion, as in the cement industry, they are estimated separately and included in the appropriate categories, in sector 2 and in sector 1 category 1.A.2. This sector makes important contributions to the emissions of heavy metals, PAH, dioxins and PCB. Regarding emissions of the main pollutants, in 2023, industrial processes (without the use of solvent) account for 7.6% of SO_2 emissions, 0.8% of NO_X, 0.1% of NH_3, 5.0% of NMVOC and 3.3% of CO. About particulate matter, in 2023 this sector accounts for 19.7% of PM10 emissions and 7.6% of PM2.5. Industrial processes make a significant contribution to the total Italian emissions of heavy metals, despite significant reductions since 1990; particularly this sector accounts for 38.0% of Pb emissions, 31.8% of Cd and 51.1% of Hg. Regarding POPs emissions, 11.4% of PAH total emissions is emitted from industrial processes as well as 27.1% of dioxins and 71.7% of PCB.

In 2023, iron and steel sector (2C1) is a key category at level assessment for PM2.5, Pb, Cd, Hg, PAH, PCDD/F and PCB; emissions from other chemical industry (2B10a) is a key category source for SO_2 emissions; emissions from 2A5a Quarrying and mining and 2A5b Construction and demolition are key categories for PM10. Emissions from 2G is a key category source for Cd and Pb, too. Food and beverage industry (2H2) is a key category for NMVOC emissions. In 1990 emissions from cement production (2A1) is a key category source for PM10 and PM2.5; other chemical industry (2B10a) is a key category for Hg and Cd and iron and steel production (2C1) is a key category for PM10, PM2.5, Cd, Hg, PAH, PCDD/F and PCB; quarrying and mining (2A5a) and construction and demolition (2A5b) are a key sources for PM10; emissions from 2G is a key source for Cd too. At trend assessment, iron and steel sector is key category for Pb, Cd, Hg, PAH PCDD/F and PCB while other chemical industry (2B10a) is a key category for Hg, 2H2 is a key category for NMVOC and 2G is a key category for Cd emissions. Emissions from 2A5a quarrying and mining are a key category for PM10.

4.2 METHODOLOGICAL ISSUES

Methodologies used for estimating emissions from this sector are based on and comply with the EMEP/EEA guidebook (EMEP/CORINAIR, 2007, EMEP/EEA, 2019, EMEP/EEA, 2023), the IPCC Guidelines (IPCC, 2006).

There are different sources relevant to estimate emissions from this sector; activity data are provided by national statistics and industrial associations, but a lot of information is supplied directly from industry. In fact, as for the energy sector, data collected in the framework of the national PRTR reporting obligation, the Large Combustion Plant directives and the European Emissions Trading Scheme are used. Other small plants communicate their emissions which are also considered individually. These processes have improved efficiency in collecting data and the exchange of information. Whenever data cannot be straight used for the inventory compilation, they are taken into account as verification practice. Environmental Reports published by industrial associations are also considered in the verification process.

4.2.1 Mineral products (2A)

In this sector emissions from the following processes are estimated and reported: cement production, lime production, glass production, quarrying&mining and construction&demolition.

Cement production (2A1), is considerable for PM2.5 emissions and accounts for 1.4% of the total national emissions in 2023.

In this category only PM10 and PM2.5 emissions are reported separately from combustion while all the other pollutant emissions are included in the energy sector in 1.A.2f category.

During the last 15 years, in Italy, changes in cement production sector have occurred, leading to a more stable structure. The oldest plants closed, wet processes were abandoned in favour of dry processes to improve the implementation of more modern and efficient technologies. Since 2011 Italy has become the second cement producer country in the EU 28 but the reduction in clinker production seems to have stopped, since 2016 clinker production at national level has kept almost the same. In 2023, 17 companies (38 plants of which: 28 full cycle and 10 grinding plants) operate in this sector: multinational companies and small and medium size enterprises (operating at national or only at local level) are present in the country. As for the localization of the operating plants: 44% is in northern Italy, 14% is in the central regions of the country and 42% is in the southern regions and in the islands (Federbeton/AITEC, several years). In Italy different types of cement are produced; as for 2023 Federbeton/AITEC, the national cement association, has characterised the national production as follows: 67% is CEM II (Portland composite cement); 11% is CEM I (Portland ordinary cement); 15% is CEM IV (pozzolanic cement) and 6% is CEM III (blast furnace cement). Clinker production has been decreasing since 2007, although from 2016 to 2019 the production values have kept very close to the amount manufactured in 2016, in 2023 clinker production shows -4.3% compared to 2022; clinker demand in cement production was about 79% in 2023 (production of clinker out of production of cement). To estimate emissions from cement production, activity data on clinker/cement production are used as provided by ISTAT (ISTAT, several years) up to 2008, MSE (MSE, several years) since 2009 up to 2018, and facility reports in the framework of the Emissions Trading Scheme national legislation. Emission factor for PM10 emissions is equal to 234 g/Mg of clinker for the whole time series and is calculated on the basis of plants emission data in the nineties. Emission factor for PM2.5 is equal to 130 g/Mg of clinker for the whole time series.

The remaining categories of mineral products (*lime production* (2A2)) industry represent less than 1% for each pollutant.

As regards 2A3 category *Glass production*, HM, PM and BC emissions are reported under 1A2f and emission factors have been provided by the research institute of the sectoral industrial association (Stazione Sperimentale del Vetro) distinguished by the different types of glass production.

About the 2A5 category, different activities are described separately as below.

As regards 2A5a *Quarrying and mining of minerals other than coal*, there is no evidence of active mines of the main minerals (i.e those indicated in the Guidebook: bauxite, copper, manganese and zinc). All these mines in Italy closed before 1990 for market reasons. At the same time there is no available data to apply a Tier 1 on other mineral mines. The value-added for this activity was adopted as a proxy to develop the other mineral ore production time series and emissions factors included in 2023 EMEP/EEA Guidebook for PM10 and PM2.5 were applied to estimate PM10 and PM2.5 emissions along the whole timeseries.

As for the category 2A5b *Construction and Demolition*, the National Institute of Statistics provides information about residential and non-residential buildings, for both categories information about volumes (for the years from 1990-2000) or surfaces (usable living areas) could be retrieved to work out a time series of activity data and to develop estimates for TSP, PM10 and PM2.5. Emission factors for TSP, PM10 and PM2.5 are those included in the 2023 EMEP/EEA Guidebook which provides specific values for residential and non-residential buildings. For the estimation of TSP, PM10 and PM2.5 emissions from construction and demolition of roads, we revised the series by applying the US-EPA algorithm included in the EMEP/EEA Guidebook. The Italian Ministry of transportations provides information about changes in the length of roads by road types, so that emission factors included in 2023 EMEP/EEA Guidebook for TSP, PM10 and PM2.5 can be applied to changes in roads surfaces. For the category 2A5c *Storage, Handling and Transport of Mineral Products*, PM2.5 emissions have been estimated and reported in the sectoral categories 2A1 Cement Production and 2A2 Lime Production. The emissions from storage, handling and transport for other minerals than the aforementioned ones might not be included in the inventory because this potential under-estimate is likely to be below the threshold of significance.

4.2.2 Chemical industry (2B)

Emissions of this sector derive from organic and inorganic chemicals processes and are usually not significant except for SO_X emissions from the production of sulphuric acid and Hg emissions from chlorine production. Emission factors derive from data collected in the framework of the national EPER/E-PRTR register as well as from EMEP/EEA and EPA Guidebooks.

As already mentioned, other chemical industry (2B10a) was key category for Cd and Hg emissions in 1990 and for SO_x emissions in 2023. Hg emissions are released from chlorine production facility with mercury cells process (EUROCHLOR, 1998). Total chlorine production in Italy amounted, in 1990, to 1,042,921 tonnes and reduced in 2023 to 217,659 tonnes. Activity production data are supplied by the National Institute of Statistics (ISTAT, several years) and since 2002 data have also been collected at industrial facility level in the national EPER/E-PRTR register. To estimate emissions from 1990 to 2001, the average emission factor supplied by EUROCHLOR for western Europe chlor-alkali production plants (EUROCHLOR, 2001) has been used, while since 2002 emission data have been supplied directly by the production facilities in the framework of the national EPER/E-PRTR. The average emission factor decreased from 1.11 g Hg/t in 2002 to zero in 2018. The reduction observed in emissions and zero emissions since 2018 are a consequence of both the conversion of production plants from the mercury cells process to the membrane technology and to the suspension of production at the existing facilities. In 2007 seven facilities carried out the chlor-alkali production: one facility had the membrane process in place, one facility was replacing mercury cells with membrane process while in the other five facilities the production was still based on the mercury cell process (Legambiente, 2007). In 2015 five facilities carried out chlor-alkali production: in four of them the membrane process was in place while one facility still operated the mercury cell process. In 2018 the four chlor-alkali facilities have the membrane process in place while the one still with mercury cells was obliged to stop the production with this technology and it is still in operation although the manufacturing process has been relying on the purchase of the intermediate products since then.

SO_x emissions reported in other chemical industry (2B10a) include emissions from sulphuric acid production and account for 5.6% of total SO_X emissions in 2023. Activity production data are supplied by the National Institute of Statistics (ISTAT, several years) and since 2004 data have also been collected at facility level in the national EPER/E-PRTR register. Emission factors from 1990 to 1994 and from 2002 are derived from emission data supplied directly by the production facilities in the framework of the national EPER/E-PRTR.

NO_x, SO_x, CO, PM and BC emissions from 2B7 Soda ash production are also estimated. In Italy there is only one plant producing soda ash and it is in the framework of the EPRTR reporting. In particular, as regards PM emissions, the operator has never reported PM10 emissions which implies that emissions are below the reporting threshold (50 t/year). As reported in the Guidebook, measurements made in some plants indicate that more than 75% of the dust emitted is made of particle size > 10 µm and that the contribution of PM10 is relatively low. Moreover, the operator in its annual environmental report estimates TSP emissions (around 200 t/y) reporting explicitly that no PM10 emissions occur. The PM10 estimated using the EMEP/EEA EFs, is about 20 Mg.

4.2.3 Metal production (2C)

The main activities in this sector are those regarding the iron and steel production. The main processes involved in iron and steel production are those related to sinter and blast furnace plants, to basic oxygen and electric furnaces and to rolling mills.

The sintering process is a pre-treatment step in the production of iron where fine particles of metal ores are agglomerated. Agglomeration of the fine particles is necessary to increase the passageway for the gases during the blast furnace process and to improve physical features of the blast furnace burden. Coke and a mixture of sinter, lump ore and fluxes are introduced into the blast furnace. In the furnace the iron ore is increasingly reduced and liquid iron and slag are collected at the bottom of the furnace, from where they are tapped. The combustion of coke provides both the carbon monoxide (CO) needed for the reduction of iron oxide into iron and the additional heat needed to melt the iron and impurities. The resulting material, pig iron (and also scrap), is transformed into steel in subsequent furnaces which may be a basic oxygen furnace (BOF) or electric arc furnace (EAF). Oxygen steelmaking allows the oxidation of undesirable impurities contained in the metallic feedstock by blowing pure oxygen. The main elements thus converted into oxides are carbon, silicon, manganese, phosphorus and sulphur.

In an electric arc furnace steel is produced from polluted scrap. The scrap is mainly produced by cars shredding and does not have a constant quality, even if, thanks to the selection procedures, the scrap quality becomes better year by year. The iron and steel cycle is closed by rolling mills with production of long products, flat products and pipes.

In 1990 there were four integrated iron and steel plants in Italy. Since 2020, there is only one of the above-mentioned plants remaining; oxygen steel production represents about 16% of the total production and the arc furnace steel the remaining 84% (FEDERACCIAI, several years). Currently, long products represent about 48.4% of steel production in Italy, flat products about 39.4%, and pipe the remaining 12.2%. Most of the flat production derives from the only one integrated iron and steel plant while, in steel plants equipped with electric ovens (almost all of them are located in the northern regions), long products are predominantly produced (e.g carbon steel, stainless steels) and seamless pipes (only one plant) (FEDERACCIAI, several years).

Basic information for Iron and steel production derives from different sources in the period 1990-2023. Activity data are supplied by official statistics published in the national statistics yearbook (ISTAT, several years) and by the sectoral industrial association (FEDERACCIAI, several years). For the integrated plants, emission and production data have been communicated by the two largest plants for the years 1990-1995 in the framework of the CORINAIR emission inventory, distinguished by sinter, blast furnace and BOF, and by combustion and process emissions. From 2000 production data have been supplied by all the plants in the framework of the ETS scheme, for the years 2000-2004 disaggregated for sinter, blast furnace and BOF plants, from 2005 specifying carbonates and fuels consumption. For 2002-2015 data have also been supplied by all the four integrated iron and steel plants in the framework of the EPER/E-PRTR registry but not distinguished between combustion and process. National experts have also been involved in the process of elaboration of the "monitoring and control plan" for the largest integrated plant in Italy in the framework of the IPPC permit. Qualitative information and documentation available on the plants allowed reconstructing their history including closures or modifications of part of the plants; additional qualitative information regarding the plants, collected and checked for other environmental issues or directly asked to the plant, permitted to individuate the main driving of the emission trends for pig iron and steel productions. Emissions from lime production in steel making industries are reported in 1A2f Manufacturing Industries and Construction category. In 2023, iron and steel sector (2C1) is key category for PM2.5, Pb, Cd, Hg, PAH, PCDD/F and PCB. In Table 4.1 relevant emission factors are reported.

Table 4.1 Emission factors for iron and steel for the year 2023

		PM10 [g/Mg]	PM2.5 [g/Mg]	Cd [mg/Mg]	Hg [mg/Mg]	Pb [mg/Mg]	PCB [mg/Mg]	PAH [mg/Mg]	PCDD/F [µg T-eq/Mg]
Blast furnace charging	Areal	60	37.5						
	Point	2.8	1.8						
Pig iron tapping	Areal	41.4	25.9	0.3	0.3	15		950	
	Point	2.0	1.2	0.3	0.3				
Basic oxygen furnace	Areal	62	54.3	25	3	850	3.6		
	Point	10.7	9.4	2.3	1.7	49	3.6		
Electric arc furnace		124	108.5	50	150	3450	3.6	1.9	4.45
Rolling mills	Areal	59	45.9					125	
	Point	28.2	21.9					125	
Sinter plant (except combustion)	Areal	16	12.8						
	Point	3.5	2.8						

PM10 emission factors for integrated plants derive from personal communication of the largest Italian producer of pig iron and steel (ILVA, 1997) while PM10 emission factor for electric arc furnace derives from a sectoral study (APAT, 2003). The Emission factors manual PARCOM-ATMOS (TNO, 1992), the EMEP/Corinair Guidebook (EMEP/CORINAIR, 2006) and the IPPC BRef Report (IPPC, 2001) provide emission factors for heavy metals while a sectoral study (APAT, 2003) provides Cd emission factors for electric arc furnace. In 2022, as reported above, work has begun to revise the EFs from the largest integrated plant (point sources) thanks to the analysis of the monitoring and control plans linked to the data collected in the framework of the IPPC permits (period 2012-2019). Emission factors derived from this survey on the IPPC permits have been applied since 2016 and relate both to combustion and process categories. Further information about combustion emissions is given in the combustion chapter. As regards the category 2C1EFs for PM emissions from blast furnace charging, pig iron tapping, basic oxygen furnace and sinter plant have been updated in the 2020 submission as for BOF emissions where Cd, Pb and Hg EFs have been updated too.

Regarding PAH emissions, for blast furnaces, results from measurements tell us that emission factor used for pig iron tapping covers also blast furnace charging while emissions from BOF are negligible. To complete the category analysis, for 1A1c category and, in particular, for coke production according to the review (EEA, 2019) PAH emission factor has been disaggregated into those deriving from the combustion process and the fugitive ones and estimated with the emission factors in the Guidebook (EMEP/EEA, 2019). Regarding POPs emissions, emission factors usually originate from EMEP/CORINAIR (EMEP/CORINAIR, 2007, EMEP/CORINAIR, 2006) except those relating to PAH and PCDD/PCDF from electric arc furnace that derive from direct measurements in some Italian production plants (ENEA-AIB-MATT, 2002). Dioxin emissions for sinter plant, and other sources within steelworks manufacturing oxygen steel occur during the combustion process and they are measured at the stack; emissions are therefore reported in the energy sector in 1.A.2a category. In 2023 the average emission factor is equal to 0.07 micrograms TEQ per Mg of sinter produced. EF is calculated yearly on the basis of measurements done in the sole existing sinter plant in Italy. As regards HCB emissions, Italy reports HCB emissions from sintering production calculated with the 2006 Guidebook ("Sources of HCB emissions.pdf" does not distinguish between combustion and process. The 2016 Guidebook provides reference to the 2006 version) EF=0.032mg/Mg in 1A2a because in this case HCB emissions are clearly linked to the combustion activities. As for other iron and steel activities, a series of technical meetings with the most important Italian manufacturers was held in the framework of the national PRTR in order to clarify methodologies for estimating POPs emissions. In the last years, a strict cooperation with some local environmental agencies allowed the acquisition of new data, the assessment of these data is still ongoing and improvements in emission estimates are expected for the next years. Thanks to the last review process in the framework of the NEC Directive (EEA, 2019) fugitive PAH emissions from coke oven (door leakage and extinction) have been estimated on the basis of 2019 EMEP/EEA Guidebook emission factors. As a consequence of the review process these emissions have been reported in 1B1b adopting the right allocation. Emission factors used in 1990 estimates generally derive from Guidebook EMEP/CORINAIR. The remaining categories of metal production industry represent about 0% for each pollutant because of the shutdown of several plants, in particular those linked to the non-ferrous production.

No plants for aluminium production by electrolysis have been working in Italy since 2012 and pollutants time series are reported, obviously, from 1990 to 2012, consequently no primary aluminium production has been occurring since 2012. Secondary aluminium production still occurs in Italy, activity data are provided annually by the statistical office of Assomet, the trade association dealing with non-ferrous metals. Emissions from secondary aluminium production are reported under the energy sector (1A2b). For that, from 2012 notation key "IE" has been reported in this category the review process. HCB emissions from secondary aluminium production are not reported and are expected to be null because these emissions derive from the degassing of aluminium when hexachloroethane is used, but this compound is banned in Italy from '90s. Further information about emissions from secondary aluminium production are included in the paragraph devoted to category 1A2b included in Chapter 3, paragraph 3.3.1.2 and 3.3.2.2.

As for the production of lead, zinc and copper (2C5, 2C6 and 2C7a categories), at the moment SO_X, HM and PM emissions are reported in the energy sector because up to now there was no information to distinguish between energy and process emissions and, above all, these processes are considered combustion processes with contact, consequently, emissions are dependent on the combustion process.

In the last year, thanks to the ETS data, it has been possible to separate CO_2 emissions in these two components and Italy is investigating the possibility of extension to other pollutants for the next submissions. In particular, in Italy no production of primary copper has ever occurred while, as regards lead and zinc, there is a sole integrated plant for the primary productions, and this makes it difficult to ensure a good breakdown. Consequently, the issue related to the allocation of emissions is not only about combustion and process but also about the different productions of different metals in the same factory. To resolve this issue, an in-depth investigation has been started with the aim of better specify the technology used on the basis of E-PRTR and IPPC permits. Thanks to the analysis of these monitoring data, it was possible to recalculate the emissions from the production of zinc and lead starting from the measurements at the chimneys since 2014, the first year of useful data (in 2013 the monitoring system covered only 3 months). The first result of this investigation has been the update of EFs since 2014 (ISPRA, 2023). For the next submission the reconstruction of the historical series in the previous years is foreseen and, finally, the distinction between process and combustion emissions. More information on the upgrade done can be found in the paragraph on the combustion of non-ferrous metals (1A2b). Anyway, for Pb, Cd and PCB the notation key IE has been added in the NFR because of the relevant emissions are reported in the energy sector.

Moreover, in response to the review process Italy explained that the Hg emission factor for copper production in the 2019 EMEP/EEA Guidebook is not applicable because it refers to primary copper production while in Italy copper production between 1990 and 1998 was derived only from secondary technologies.

4.2.4 Other production (2G – 2H – 2I – 2L)

2G sector includes NMVOC emissions due to the use of lubricants as well as all potential emissions from the use of tobacco and explosives/fireworks. In 2H sector, non-energy emissions from pulp and paper as well as food and drink production, especially wine and bread, are reported. TSP emissions from wood processing are included and reported in 2I, Lead emissions from batteries manufacturing can be found in 2L sector.

Emissions from these categories are usually negligible except for NMVOC emissions from food and drink (2H2) accounting for 3.1% of the national total in 2023 and Cd from fireworks (2G) accounting for 8.9% of the national total, both are key categories in 2023. Emissions from food and drink (2H2) refer to the processes in the production of bread, wine, beer and spirits. Activity data are derived from official statistics supplied by the National Institute of Statistics (ISTAT, several years) and relevant industrial associations. Time series of bread production is reconstructed for the '90 years on the basis of family surveys from the national Institute of statistics (ISTAT) while from 1998 data are those reported in the PRODCOM statistics officially communicated by ISTAT to EUROSTAT. In the '00 years, bread production has changed from fresh artisanal production to a more industrial oriented production, without any impact on the total. For wine, beer and spirits the statistical information on activity data is much more reliable and their trends are driven by the seasonal variation (for wine) or market demand (for beer) while for spirits it is mostly driven by a change in the personal habits and corresponding consumptions. Emission factors are those reported in the EMEP/CORINAIR Guidebook and, in lack of national information, they are assumed constant for the whole time series (CORINAIR, 1994; EMEP/CORINAIR, 2006).

Regarding 2G category (other product use) all potential emissions have been estimated both for the use of tobacco and fireworks; NMVOC, SO_X, NO_X, CO, NH_3 Cd, Pb, PM10, PM2.5, PCDD, Benzo(a)pyrene and PAH are estimated. For activity data, as regards fireworks, Eurostat data on import, export and production of fireworks have been used, while data on consumption of tobacco was collected from the Ministry of Health, observatory of tobacco smoking. Emission factors are those reported in the 2019 EMEP/EEA Guidebook (EMEP/EEA, 2019). NMVOC emissions from use of lubricants are also estimated. Activity data are from the energy statistics (MASE, several years) while emission factor is from the EMEP/EEA Guidebook (EMEP/EEA, 2019).

Pulp and paper industry (2H1) referred to the acid sulphite and neutral sulphite semi-chemical processes up to 2007 and only to the neutral sulphite semi-chemical process for 2008 and 2009, while the kraft process was not present in Italy. Emissions of NO_X, NMVOC, SO_X and PM were estimated for those years on the basis of activity data provided by the two Italian production plants. In 2008 the bleached sulphite pulp production stopped and in 2009 the neutral sulphite semi-chemical pulp process plant also closed. So, for the IPPU inventory purposes, there has not been any production of pulp and paper after 2009 and consequently no emissions have been estimated. Acid sulphite process emissions are calculated for SO_X, NMVOC and NO_X on the basis of EFs available in the Best Available Techniques Reference Documents report (BRef report), for PM10 on the basis of EF in the USEPA Guidebook (54% PST) while for PM2.5 and BC emission profiles reported in the EMEP/EEA 2023 Guidebook (Table 3.3) have been used. For neutral sulphite semi-chemical process the emission factors used through the time period referred for SO_X, NMVOC and NO_X to CORINAIR 1992, EMEP/CORINAIR Guidebook, and for NO_X, from 1996, data were communicated by the operator of the plant.

NMVOC emissions include emissions from chipboard production where activity data are those in the FAOSTAT database for particle board and the emission factor 500 g/Mg product is from "Corinair 1992 Default Emission Factors Handbook".

In 2I category, TSP emissions from wood processing are reported. Considering that in Italy wood furniture production start from wood panels and sawnwood, emissions are estimated on the basis of statistics from the FAOSTAT database for that kind of wood production and the emission factor in the 2023 EMEP/EEA Guidebook, which is equal to 1 kg/t of wood product.

In 2L category lead emissions from batteries manufacturing are reported. Activity data are provided by the non-ferrous metal industrial association (ASSOMET) and refer to the amount of lead used for the batteries production; the emission factor has been provided by the relevant industrial association (ANIE) calculated on the basis of average lead concentration to the chimney, equal to 0.2 mg/Nmc, the average flow (equal to 15 Nmc/h/tonnes Pb) and the annual number of hours.

4.3 TIME SERIES AND KEY CATEGORIES

The following sections present an outline of the main key categories, and relevant trends, in the industrial process sector. Table 4.2 reports the key categories identified in the sector.

Table 4.2 Key categories in the industrial processes sector in 2023.

	2A1	2A2	2A5a	2A5b	2B1	2B2	2B3	2B6	2B7	2B10a	2C1	2G	2H1	2H2	2L
	%														
SO_x					0.01			0.01	0.21	5.63	1.69	0.07			
NO_x					0.03	0.05	0.004	0.003	0.02	0.29	0.41	0.02			
NH_3					0.002	0.0001			0.04	0.02		0.08			
NMVOC					0.01					0.18	0.34	1.21	0.15	3.11	
CO					0.00				0.32	0.73	2.02	0.22			
PM10	1.78	0.53	2.89	10.77				0.0003	0.01	0.16	1.83	1.68		0.01	
PM2.5	1.40	0.15	0.41	1.53				0.0003	0.01	0.09	2.18	1.84			
BC	0.35	0.01						0.00005	0.002	0.01	0.07				
Pb											30.80	6.10			1.06
Cd										0.97	21.93	8.92			
Hg											51.12				
PAH											11.43	0.01			

	2A1	2A2	2A5a	2A5b	2B1	2B2	2B3	2B6	2B7	2B10a	2C1	2G	2H1	2H2	2L
							%								
Dioxin											27.08	0.00001			
HCB															
PCB											71. 69				

Note: key categories are shaded in blue

There is a general reduction of emissions in the period 1990 - 2023 for most of the pollutants due to the implementation of different directives at European and national level. A strong decrease is observed especially in the chemical industry due to the introduction of relevant technological improvements and the complicated international situation which led to the considerable reduction of some productions.

4.3.1 Mineral products (2A)

As mentioned above, TSP, PM10 and PM2.5 emission factors for cement production are set constant from 1990 to 2020 while SO_2 emissions have been set as not occurring along the whole timeseries as they originate from fuel combustion and consequently, they are allocated under 1A2f. The trends of TSP, PM10 and PM2.5 emissions follow those of the activity data. In Table 4.3, activity data, TSP, PM10 and PM2.5 emissions from cement production (2A1) are reported.

Table 4.3 Activity data and PM10 emissions from cement production, 1990 – 2023 (Gg)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Cement production [Gg]	42,414	35,432	41,119	47,291	34,283	20,825	18,060	20,621	18,797	18,815
Clinker production [Gg]	29,785	28,778	29,816	33,122	25,239	15,527	13,389	15,162	15,665	15,009
TSP emissions (Gg)	8	7	8	9	7	4	3	4	4	4
PM10 emissions [Gg]	7	7	7	8	6	4	3	4	4	4
PM2.5 emissions [Gg]	4	4	4	4	3	2	2	2	2	2

In Table 4.4, activity data, TSP, PM10 and PM2.5 emissions from quarrying and mining of other mineral than coal (2A5a) are reported.

Table 4.4 Activity data and PM10 and PM2.5 emissions from 2A5a (1990-2023)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Annual production [Gg]	190	190	217	196	163	155	102	201	112	114
TSP emissions [Gg]	19	19	22	20	17	16	10	21	11	12
PM10 emissions [Gg]	10	10	11	10	8	8	5	10	6	6
PM2.5 emissions [Gg]	1	1	1	1	1	1	1	1	1	1

In Table 4.5 activity data, TSP, PM10 and PM2.5 emissions from construction and demolition of buildings and roads (2A5b) are reported.

Table 4.5 Activity data and TSP, PM10 and PM2.5 emissions from 2A5b (1990-2023)

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Buildings+roads [1000 m2]	88,813	89,037	77,421	100,685	110,213	53,571	54,167	44,116	46,523	29,391
TSP emissions (Gg)	0.125	0.128	0.110	0.139	0.174	0.085	0.086	0.067	0.072	0.071
PM10 emissions [Gg]	0.038	0.039	0.033	0.042	0.052	0.026	0.026	0.020	0.021	0.021
PM2.5 emissions [Gg]	0.004	0.004	0.003	0.004	0.005	0.003	0.003	0.002	0.002	0.002

4.3.2 Chemical industry (2B)

Other chemical industry (2B10a) was a key category for Cd and Hg emissions in 1990 and for SO_x in 2023 and for Hg at trend assessment. Hg emissions refer to chlorine production with mercury cells process; in Table 4.6, activity data and Hg emissions from chlorine production are reported. As reported in paragraph 4.1, to estimate emissions from 1990 to 2001, the average emission factor supplied by EUROCHLOR for western Europe chlor-alkali production plants has been used, while from 2002 emission data have been supplied directly from the production plants in the framework of the national EPER/E-PRTR reporting obligation. The average emission factor decreased from 1.11 g Hg/t in 2002 to zero in 2018. The reduction observed and zero Hg emissions since 2018 is a consequence of the conversion of production plants from the mercury cells process to the membrane technology but it depends also on suspensions of production processes at some facilities.

Table 4.6 Activity data and Hg emissions from chlorine production, 1990 – 2023

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Activity data [Gg]	1,043	869	786	535	258	218	241	236	237	218
Hg emissions [Mg]	3	2	1	0.48	0.12	0.04	-	-	-	-

SO_X emissions are prevalent from carbon black production. Sulphuric acid production, titanium oxide, other sulphate and phthalic anhydride productions are other sources reported in 2B10a and emitting SO_X. Activity data and emission factors for these sources are collected at the plant level on annual basis.

4.3.3 Metal production (2C)

Emission trend of HMs, PCB and PCDD/PCDF is driven mainly by the electric arc furnaces iron and steel production which increased from 15.1 Mt in 1990 to 19.6 Mt in 2008; in 2009, because of the economic crisis, steel production from electric arc has decreased substantially and since 2010 the production has increased again up to 20.0 Mt in 2018 and 20.4 Mt in 2021, with a dip in 2020 to 17.01 Mt because of the pandemic. In 2023 EAF production is equal to 18.1 Mt. In Table 4.7, activity data and HM, PCB and PCDD/PCDF emissions from electric arc furnace (EAF) and from the whole sector 2C1 are reported, but dioxins emissions from sinter plant are reported in the energy sector in 1.A.2f category. In 2023 average emission factor is equal to 0.07 micrograms TEQ per Mg of sinter produced. Emissions from iron and steel process in integrated plant derive from blast furnace charging, pig iron tapping, basic oxygen furnace steel plant, sinter and pelletizing plant and rolling mills.

Table 4.7 Activity data and HMs, PCB and PCDD/PCDF emissions from electric arc furnace and 2C1, 1990 – 2023

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Steel production EAF [kt]	15,102	16,107	15,879	17,661	17,115	17,255	17,007	20,416	18,190	18,086
Cd emissions EAF [Mg]	1.1	1.1	0.8	0.9	0.9	0.9	0.9	1.0	0.9	0.9
Cd emissions 2C1 [Mg]	1.3	1.4	1.1	1.2	1.1	1.0	0.9	1.0	0.9	0.9

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Hg emissions EAF [Mg]	2.3	2.4	2.4	2.6	2.6	2.6	2.6	3.1	2.7	2.7
Hg emissions 2C1 [Mg]	2.3	2.5	2.4	2.7	2.6	2.6	2.6	3.1	2.7	2.7
Pb emissions EAF [Mg]	52.1	55.6	54.8	60.9	59.0	59.5	58.7	70.4	62.8	62.4
Pb emissions 2C1 [Mg]	61.1	65.7	64.1	71.0	66.5	63.7	58.9	70.7	63.0	62.6
PCB emissions EAF [kg]	54.4	58.0	57.2	63.6	61.6	62.1	61.2	73.5	65.5	65.1
PCB emissions 2C1 [kg]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
PCDD/F emissions EAF [g T-eq]	67.2	71.7	70.7	78.6	76.2	76.8	75.7	90.8	80.9	80.5
PCDD/F emissions 2C1 [g T-eq]	67.2	71.7	70.7	78.6	76.2	76.8	75.7	90.8	80.9	80.5

For Pb and Hg, the same EFs have been used for the whole time series (derived by the EMEP/CORINAIR Guidebook), while for Cd a national emission factor, equal to 50 mg/t, was available thanks to a sectoral study (APAT, 2003) and refers to the years after 1997. This study shows range < 1-54 mg/t and the value set to 50 mg/t was chosen for conservative reason being more consistent with the old one; this value should include technology progresses occurred in the iron and steel production activities in those years. Lacking information for the years backwards, the default CORINAIR EF was used. For PCB and PCDD/Fs, emission factors are constant from 1990 to 2023 and emission trends are ruled by the activity data. For SO_2 and PM emissions from lead, zinc and copper production they are included and reported in the energy relevant sector. In Italy there is a sole integrated plant for the primary production of zinc and lead and this makes it difficult to ensure a good breakdown between the energy and the process sectors and the activities. During the latest years more information about the plant has been supplied taking advantage of a direct contact with the facility through the E-PRTR registry but it was not sufficient to split the emissions. Thanks to a deep survey on this category based on the analysis of IPPC permits and data available from the monitoring and control plan, the estimates for Pb, Cd, Zn, PM, NO_x e SO_2 have been revised since 2014. The analysis of this documentation will carry out further improvement such as, for example, a better allocation of emissions between combustion and process but also between the zinc and the lead production. In some cases different trend of emissions was due to the temporary closure of some parts of the plant. For example, in 2009 no contribution of Waelz was registered because the plant was stopped from January to October; the Kivcet plant was also shut down from May 2009 to 2012 and during this period the optimization of the Waelz furnace exhaust dedusting was carried out. The operation of the plant in 2023 was characterised by a reduced run due to the energy crisis in the European market, against which a a strategic shutdown was planned, in particular for the Kivcet and Zinc line. For this reason, the emissions for the year 2023 are generally lower than in previous years and come almost entirely from the Waelz plant. Detailed information on the integrated plant, of its transformations and emissions are reported in the ISPRA Technical note (ISPRA, 2023).

As regards EAF too, EF was update on the basis of a sectoral study (APAT, 2003) which reports the development of abatement technologies in the '90s in Italy and the consequent evolution in the plants with the installation of fabric filters; but in this case the update is referred to 1990-1999 because the EF used in previous submissions concerned already abated emissions. In Table 4.8, activity data and PAH emissions from integrated plants and from the whole sector 2C1 are reported.

Table 4.8 Steel production data and PAH emissions from integrated plants, 1990 – 2023

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Pig iron production [Gg]	11,852	11,678	11,209	11,424	8,555	5,051	3,406	4,111	3,390	3,027
Steel production BOF [Gg]	10,365	11,664	10,744	11,688	8,635	4,763	3,371	3,996	3,409	2,970
PAH emissions i.p.* [Mg]	41.9	41.3	11.7	12.1	9.2	5.8	4.1	5.0	4.2	3.8

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
PAH emissions 2C1 [Mg]	44.9	44.5	14.3	15.1	11.9	8.2	6.4	7.7	6.6	6.2

4.3.4 Other production (2G – 2H – 2I –2L)

These categories include the use of fireworks, lubricants and tobacco (2G), Pulp & paper and food & drink (2H), wood processing (2I) and batteries manufacturing (2L). NMVOC emissions from these categories derive from 2G and 2H and they are equal to 38.9 Gg accounting for 4.5% of the national total in 2023, in particular emissions from food and drink (2H2) accounting for 3.1% of the national total. Emissions from this last category refer to the processes in the production of bread, wine, beer and spirits. Emission factors are assumed constant for the whole time series. In Table 4.9, activity data and NMVOC emissions are reported.

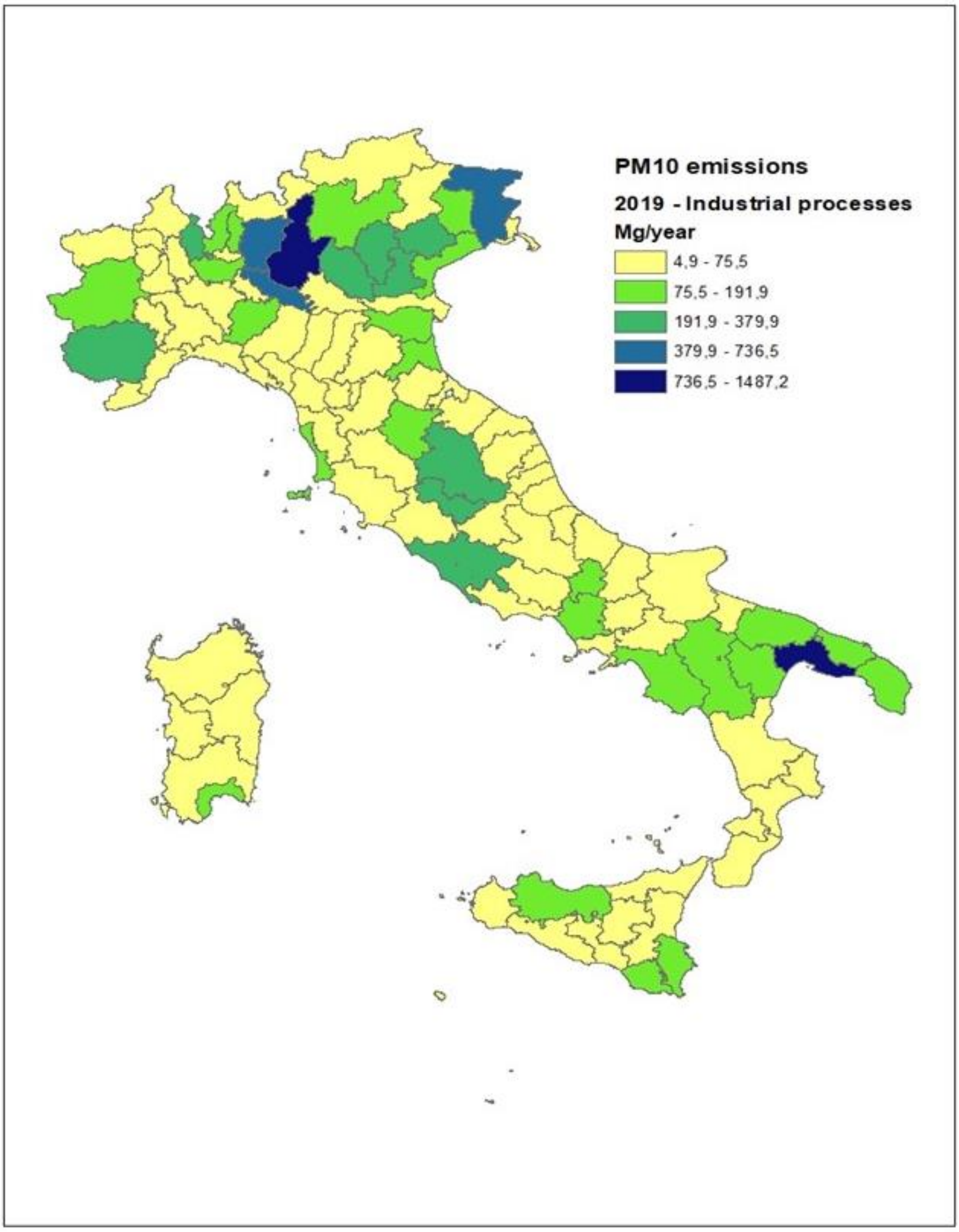
Table 4.9 Activity data and total NMVOC emissions, 1990 – 2023

		1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
2G	Fireworks – [Mg]	3,122	3,122	10,686	13,108	10,748	5,480	4,762	9,165	10,052	15,819
2G	Use of tobacco – [Mg]	92,573	92,573	101,973	94,674	90,721	79,823	70,030	69,354	70,048	72,773
2G	Lubricants – [Gg]	673	630	638	580	429	403	338	372	327	365
2H	Pulp and paper – [Gg]	140.4	82.2	80.0	80.4	NO	NO	NO	NO	NO	NO
2H	Activity data - Bread [Gg]	4,153	3,882	3,565	4,109	4,161	3,877	4,666	4,114	3,791	4,493
2H	Activity data – Wine [10^6 dm^3]	5,521	5,620	5,409	5,057	4,673	5,073	5,433	5,319	5,636	4,445
2H	Activity data – Beer [10^6 dm^3]	1,215	1,199	1,258	1,280	1,281	1,429	1,583	1,764	1,835	1,743
2H	Activity data – Spirits [10^6 dm^3]	268	232	206	161	115	98	111	106	103	105
TOT	NMVOC emissions [Gg]	52.5	48.6	46.8	45.9	39.9	37.2	39.7	38.0	35.4	38.9

4.4 QA/QC AND VERIFICATION

Activity data and emissions reported under EU-ETS and the national EPER/EPRTR register are compared to the information provided by the industrial associations. The general outcome of this verification step shows consistency among the information collected under different legislative frameworks and information provided by the relevant industrial associations. Every five years emissions referring to 1990-2015 are disaggregated at regional and provincial level and figures are compared with results obtained by regional bottom-up inventories. From 2015 onwards the disaggregation at local level takes place every four years, so up to now the disaggregation of the national inventory covers estimates for the years: 1990, 1995, 2000, 2005, 2010, 2015 and 2019. PM10 emissions disaggregated at local level are also used as input for air quality modelling. The distribution of PM10 emissions from the industrial processes sector at NUTS3 level for 2019 is reported in Figure 4.1; methodologies are described in the relevant publication (ISPRA, 2022).

Figure 4.1 PM10 emissions from industrial processes in 2019 (t)



4.5 RECALCULATIONS

4.5.1 Mineral industry (2A)

Recalculations occur for emissions from category 2.A.5.b in 2022 due to the update of activity data.

4.5.2 Chemical industry (2B)

Recalculations occur in 2021 and 2022 due to the update of activity data.

4.5.3 Metal industry (2C)

No recalculations occur for this source category.

4.5.4 Other product use (2G)

Recalculation occurred for NMVOC emissions from lubricants use because of the update of the activity data.

4.5.5 Other industrial processes (2H)

Recalculations occur for emissions from category 2.H.2 in 2022 due to the update of activity data.

4.6 PLANNED IMPROVEMENTS

Activities 2C5, 2C6 and 2C7 are under investigations to allocate emissions between combustion and process.

5 IPPU - SOLVENT AND OTHER PRODUCT USE (NFR SECTOR 2)

5.1 OVERVIEW OF THE SECTOR

In this sector all non-combustion emissions from other industrial sectors than manufacturing and energy industry are reported. Emissions are related to the use of solvent in paint application, degreasing and dry cleaning, chemical products, manufacture and processing and other solvent use, including emissions from road paving with asphalt and asphalt roofing activities. NMVOC emissions are estimated from all the categories of the sector as well as PM for polyester and polyvinylchloride processing, in the chemical product category, and for asphalt processes and PAH emissions from the preservation of wood in the other solvent use. The categories included in the sector are specified in the following.

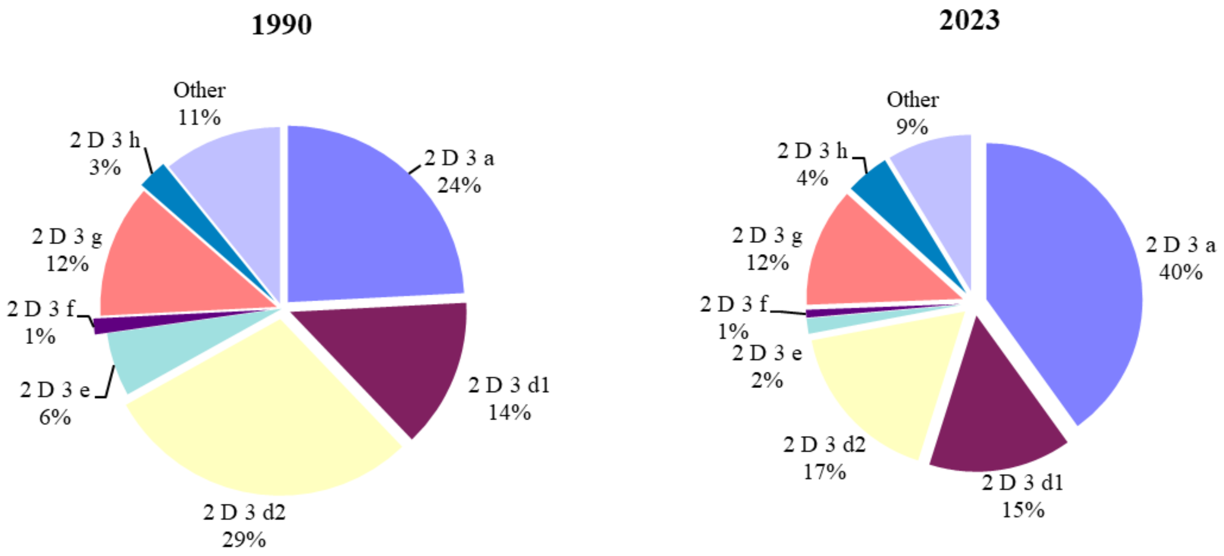
- 2D3a Domestic solvent use includes emissions from the use of solvent in household cleaning and car care products as well as cosmetics.
- 2D3b Road paving with asphalt includes emissions from production and use of asphalt for road paving.
- 2D3c Asphalt roofing includes emissions from the manufacturing of roofing products and the blowing of asphalt.
- 2D3d1 Decorative coating includes emissions from paint application for construction and buildings, domestic use and wood products.
- 2D3d2 Industrial coating includes emissions from paint application for manufacture of automobiles, car repairing, coil coating, boat building and other industrial paint application.
- 2D3e Degreasing includes emissions from the use of solvents for metal degreasing and cleaning.
- 2D3f Dry cleaning includes emissions from the use of solvent in cleaning machines.
- 2D3g Chemical products, manufacture and processing covers the emissions from the use of chemical products such as polyurethane and polystyrene foam processing, manufacture of paints, inks and glues, textile finishing and leather tanning.
- 2D3h Printing includes emissions from the use of solvent in the printing industry
- 2D3i Other product use addresses emissions from glass and mineral wool enduction, fat edible and non-edible oil extraction, preservation of wood, application of glues and adhesives, vehicles dewaxing.

NMVOC emissions from 2D3a, 2D3d, 2D3g and 2D3i are key categories in 2023; the same categories were also key categories in 1990. For PM10 and PM2.5, the category 2D3i is a key category for 2023. For the trend 1990-2023, 2D3a and 2D3g result as key categories.

The sector accounts, in 2023, for 44.1% of total national NMVOC emissions, whereas in 1990 the weight out of the total was equal to 31.5%. Total sectoral NMVOC emissions decreased by 39.3%, between 1990 and 2023. PM10 and PM2.5 account for 2.1% and 2.0%, respectively, in 2023. PAH emissions are also estimated but they account for about 1%.

In Figure 5.1 the share of NMVOC emissions of the sector is reported for the years 1990 and 2023.

Figure 5.1 Share of NMVOC emissions for the solvent use sector in 1990 and 2023.



5.2 METHODOLOGICAL ISSUES

The sector is characterized by a multitude of activities which implies that the collection of activity data and emission factors is laborious. A lot of contacts have been established in different sectors with industrial associations and documentation has been collected even though improvements are still needed, especially in some areas. Emissions of NMVOC from solvent use have been estimated according to the methodology reported in the EMEP/EEA guidebook, applying both national and international emission factors. Country specific emission factors provided by several accredited sources have been used extensively, together with data from the national EPER/PRTR registry; in particular, for paint application (Offredi, several years; Innovhub, several years), solvent use in dry cleaning (ENEA/USLRMA, 1995), solvent use in textile finishing and in the tanning industries (UNIC, several years). Basic information from industry on percentage reduction of solvent content in paints and other products has been applied to EMEP/EEA emission factors in order to evaluate the reduction in emissions during the period considered.

A more detailed description is reported for the 2023 key categories of NMVOC emissions in the following sections. A description of the estimation process for road paving with asphalt and asphalt roofing is also included.

5.2.1 Domestic solvent use (2D3a)

The category comprises a lot of subcategories whose emissions, specifically NMVOC, originate from the use of solvent in household cleaning and car care products as well as cosmetics. Emissions from this category have been calculated using a detailed methodology, based on VOC content per type of consumer product. Emissions from domestic solvent use comprise emissions from the use of products for household and cleaning and for cosmetics which are derived as described in the following.

Activity data

Activity data are expressed as the sum, in tonnes, of household and cleaning products and cosmetics.

Household and cleaning products: data are communicated by the National Association of Detergents and Specialties for industry and home care (Assocasa, several years) either by personal communications or Association Reports and refer to the consumption of soaps and detergents and cleaning and maintenance products.

Cosmetics: data are the sum of cosmetics products in aerosol form and other cosmetics. Figures of cosmetics in aerosol form are provided by the Italian Aerosol Association (AIA, several years (a) and (b)) and refer to the number of pieces of products sold for personal care (spray deodorants, hair styling foams and other hair care products, shaving foams, and other products). These figures are then converted in tonnes by means of the capacity of the different cosmetics containers.

Figures for other cosmetics products are derived by the Production Statistics Database (Prodcom) by the National Institute of Statistics (ISTAT, several years) by difference with the previous aerosol data.

Time series of cosmetics production is reconstructed by means of the annual production index, considering the year 2000 as the base year because this is the year where production national statistics and Prodcom data coincide. The next step is the calculation of apparent consumption taking into account import-export data derived by the National Association of Cosmetic Companies (UNIPRO, several years). Since these figures also include aerosol cosmetics, the amount of aerosol cosmetics is subtracted.

Final consumption is therefore estimated.

<u>*Emission factors*</u>

NMVOC emission factors are expressed in percentage of solvent contained in products.

Household and cleaning products: figures are communicated by the relevant industrial association, ASSOCASA, by personal communications (Assocasa, several years). For leather, shoes, wood etc. and car maintenance products, figures are taken from BiPro Association (EC, 2002). For insecticides, emission factors derive from national studies at local level (Techne, 2008). The emission factor of disinfectants for domestic use, such as hand sanitizers is taken from the EMEP/EEA Guidebook (EMEP/EEA, 2023) and is in line with the results of the studies by ESIG and TNO (ESIG, 2024; TNO, 2024).

Cosmetics: for aerosol cosmetics, the emission factor is communicated by the Italian Aerosol Association for the year 2004 and supposed constant from 1995. For other cosmetics, information from BiPro has been considered (EC report 'Screening study to identify reductions in VOC emissions due to the restrictions in the VOC content of products', year 2002 (EC, 2002)), and supposed constant from 1996.

5.2.2 Road paving with asphalt (2D3b)

The category includes NMVOC and PM emissions from the application of asphalt to road. The emission factors for NMVOC emissions from road paving are set constant along the whole timeseries and are equal to 16 g $NMVOC/Mg_{asphalt}$. The activity data are yearly provided by the national association of producers while the EF is taken from the EMEP/EEA Guidebook.

5.2.3 Asphalt Roofing (2D3c)

The category includes CO and NMVOC emissions from the application of asphalt to insulate (waterproofing) the roof of buildings. The emission factors for CO and NMVOC emissions from asphalt roofing are set constant along the whole timeseries and are equal to 38 g $CO/10^3$ m^2 and 0.085 g $NMVOC/10^3$ m^2. The activity data are yearly provided by the national association of producers while the EF is taken from the EMEP/EEA Guidebook with the assumption that 1000 m^2 of asphalt material corresponds to 4 Mg. The following table describes AD, EF and emissions for CO and NMVOC between 1990 and 2023.

Table 5.1 AD, EF and emissions for CO and NMVOC from asphalt roofing, 1990-2023.

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Activity data – Asphalt roofing [10^6 m^2]	200.0	200.0	200.0	240.0	204.0	152.2	117.6	134.4	130.6	134.4
CO emissions [Gg]	0.008	0.008	0.008	0.009	0.008	0.006	0.004	0.005	0.005	0.005
NMVOC emissions [Gg]	0.017	0.017	0.017	0.020	0.017	0.013	0.010	0.011	0.011	0.011

5.2.4 Decorative coating (2D3d1)

The category includes NMVOC emissions from the application of paint for construction and buildings, domestic use and wood products. Activity data on the consumption of paint for construction and buildings and related domestic use are provided by the Ministry of Productive Activities for 1990 and 1991 (MICA, 1999) and updated on the basis of production figures provided annually by the National Institute of Statistics (ISTAT, several years). From 2007 onwards, data are provided by SSOG (Stazione Sperimentale per le industrie degli Oli e dei Grassi, Experimental Station for Oils and Fats Industries) (Innovhub, several years), which collects information and data regarding national production and imports for paint categories set out in the directive 2004/42/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products. The purpose of this directive is to limit the total content of VOCs in certain paints and varnishes and vehicle refinishing products in order to prevent or reduce air pollution resulting from the contribution of VOCs to the formation of tropospheric ozone. The directive sets maximum VOCs content limit values for some paints and varnishes. As for emission factors, those for construction and buildings are taken from the EMEP/EEA guidebook and are considered constant till 2009, whereas the default values for domestic use vary in consideration of the different share between solvent and water content in paint throughout the years. In particular, the variation of emission factor from 1990 to 2000 is equal to 35% - 65% up to 25% - 75% in 2000, on the basis of information supplied by industry on the increase of water based paints products in the market. From 2010, emission factors are calculated taking into account maximum VOC content limit values for paint and varnishes set out in Annex II A of Directive 2004/42/EC and data collected by SSOG (Innovhub, several years). The comparison of national emission estimates for this category with those produced by IIASA for 2010 resulted in similar values. On the other hand, information on activity data and emission factors for emissions from wood products are provided by the national association of wood finishing (Offredi, several years). Emission factors have been calculated for 1990, 1998 and 2003 on the basis of information provided by the industrial association distinguishing the different type of products which contain different solvent percentages. Data have been supplied also for the years 2005 and 2006. Actually, we are keeping constant the 2006 value unless the association provides us with updated information. For previous years, values have been interpolated.

In this category, emissions from paint application in construction and buildings are the largest contributor to national NMVOC emissions and the relevant share has grown considerably in recent years. NMVOC emissions due to the use of paint and other products except from industrial coating could not be controlled properly in the past since the EU Directive 2004/42/EC entered into force. This directive, transposed into the Italian legislation in 2004, sets out maximum VOC content for many paint, varnishes and vehicle refinishing products that had to be achieved in two steps. The early limit values, to be respected from 2007 till 2009, did not lead to a significant reduction of NMVOC emissions, while the latest values, that had to be respected from 2010 onwards, brought to a significant decrease.

5.2.5 Industrial coating (2D3d2)

The category includes emissions from paint application for manufacture of automobiles, car repairing, coil coating, boat building and other industrial paint application. Activity data on the number of vehicles are provided by the National Automobile Association (ACI, several years) in the Annual Statistical Report and the emission factors are those reported by the main automobile producers on the relevant activity in their environmental reports and communicated from 2003 in the framework of E-PRTR. For the paint used in car repairing, activity data are provided by the Ministry of Productive Activities for 1990 and 1991 (MICA, 1999) and updated on the basis of production figures provided annually by the National Institute of Statistics (ISTAT, several years). The default emission factor (provided by the EMEP/EEA guidebook) used from 1990 to 1995 equal to 700 g/kg paint is also confirmed by the European guidelines for car repairing provided by the Conseil Europeen de l'Industrie des Peintures (CEPE, 1999). The reduction of the emission factor in 1999 (13% of 1995) is applied on the basis of information on different shares between solvent and water based paint throughout the years provided by the national study PINTA, Piano nazionale di tutela della qualità dell'aria (ENEA, 1997). From 1996 to 1999 the reduction is linear. From 1999 to 2006 the value is kept constant. From 2007 onwards emission factors have been calculated taking into account the maximum VOC content limit values for paint and varnishes set out in Annex II B of

Directive 2004/42/EC and data collected by SSOG. The Italian implied emission factor is the weighted average of the different products used in this activity where data are collected at detailed level and communicated within the European Directive. The trend is driven by the increase in the last years of the use of primers and special finishes. Similar trend is noted for the construction and building and domestic paints where the variability is mainly due to the percentage of solvent based paint product used out of the total paints.

Concerning coil coating, boat building and other industrial paint application, activity data are provided by the Ministry of Productive Activities for 1990 and 1991 (MICA, 1999) and updated annually by the National Institute of Statistics (ISTAT, several years). Emission factors are taken from the EMEP guidebook considering the national legislation where relevant. Emission factors of the other industrial paint application from 1990 to 1995 are constant and derive from the 1999 EMEP/CORINAIR guidebook. The reduction of the emission factor from 1996 to 2004 is applied on the basis of information on different share of paints throughout the years provided by the national study PINTA. From 2010, the value of the 1999 Guidebook has been chosen considering the further reduction of the sector (in PINTA, the reduction for 2005 with respect to 1995 is equal to 37%, and for 2010 64%; considering the default emission factor 250 g/kg of paint, the reduction is equal to 53%). NMVOC emissions from this category have been decreasing constantly since the nineties, when all industrial installations have been subjected to permits from local authorities. Since then, most of the installations have to comply with emission limit values and technological requirements imposed at regional level, taking into account the EU directives on industrial emissions (i.e. Directive 99/13/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations (EC, 1999)) and often going beyond the European legislation. With regard to car repairing the emission cut from 2007 onwards is mainly due to the maximum contents of VOC set by EU Directive 2004/42/EC (EC, 2004).

5.2.6 Degreasing (2D3e)

NMVOC emissions have been estimated for this category. The emission factors used are constant from 1990 to 1999, equal to 700 g NMVOC/kg solvent used, and from 2000, equal to 460 g NMVOC/kg solvent as specified in the EMEP/EEA Guidebook. According to the information provided by the National Industrial Association, due to technological improvements, the amount of solvent used in the products decreased during the period. Activity data, solvent used, are also provided by the relevant industrial association (Federchimica, several years).

Table 5.2 AD, EF and emissions for NMVOC from metal degreasing 2D3e, 1990-2023.

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Activity data – Degreasing [Gg]	66.6	42.0	33.6	29.9	26.8	24.1	21.8	21.4	20.9	20.8
NMVOC emissions [Gg]	46.1	27.6	15.0	13.3	11.9	10.6	9.6	9.4	9.2	9.1

5.2.7 Dry cleaning (2D3f)

Concerning dry cleaning, activity data, equal to 30,000 machines, remain unchanged throughout the time series and the emission factor is calculated based on the allocation of machines to closed-circuit (CCM) and open-circuit (OCM). Different amounts of solvent are used in these machines and have different emission factors. The emission factors are calculated assuming that in 1990 the closed-circuit machines were 60%, 90% in 1995 and up to 100% in 1999.

The average consumption of solvent per machine is equal to 258 kg/year for CCM and 763 kg/year for OCM, as derived from a national study by ENEA/USL-RMA (ENEA/USL-RMA, 1995). It is assumed that only perchlorethylene is used. These values are multiplied by the emission factors of the EMEP Guidebook, referred to the amount of solvent consumed (equal to 0.4 and 0.8 kg/kg of solvent, for CCM and OCM, respectively) and then the average annual emission factor was calculated based on the percentage distribution of closed and open circuit machines.

5.2.8 Chemical products, manufacture and processing (2D3g)

The category comprises emissions from the use of chemical products such as polyester, polyurethane, polyvinylchloride and polystyrene foam processing, manufacture of paints, inks and glues, textile finishing and leather tanning.

Activity data for polystyrene and polyurethane are derived from the relevant industrial associations, and ISTAT (ISTAT, several years), whereas emission factors are from the EMEP/EEA guidebook. For what concerns polyurethane, the relevant national industrial association has communicated that the phase out of CFC gases occurred in the second half of nineties and the blowing agent currently used is penthane. Because of manufacturing plants have abatement system in place, PM emissions could all be considered as PM2.5.

As for polyvinylchloride (PVC), activity data and emission factors are supplied in the framework of the national PRTR. NMVOC emissions are entirely attributed to the phase of PVC production; no use of solvents occurs in the PVC processing. This information has been provided by the relevant industrial plant, EVC Italy, in 2001. Because of manufacturing plants have an abatement system in place, PM emissions could all be considered as PM2.5.

For the other categories, activity data are provided by the relevant industrial associations and by ISTAT, while emission factors are taken from the EMEP/EEA guidebook considering national information on the solvent content in products supplied by the specific industrial associations.

As regards rubber processing, emission factors for the first years of nineties have been provided by the industrial association. From 1997, the emission factor from the EMEP/EEA Guidebook has been used and kept constant.

For the glues manufacturing category, emission factors for 1990 are derived from the 1992 EMEP/CORINAIR guidebook. The trend of emission factor is estimated on the basis of the trend of the emission factor for consumption of glue (as indicated by the industrial association). From 1995 to 2004, the industrial association communicated data on consumption and solvent content by product. The reductions from 2000 are based on the assumptions of PINTA. From 2004 the emission factor has been assumed constant in lack of updated information. For previous years, values have been interpolated.

As regards leather tanning, the emission factor for 1990 is from Legislative Decree 152/2006, equal to the maximum VOC content limit value (150 g/m^2). For 2000 and 2003, emission factors have been calculated on the basis of emission figures derived by the national studies on the major leather tanning industries and statistical production. From 2000, emission factors are taken from the environmental reports of the relevant industrial association (UNIC, several years).

As regards asphalt blowing and potential PAH and Benzo(a)pyrene emissions, according to the relevant industrial association PAH emissions are negligible because all the asphalt blowing plants have abatement filter system of PM and afterburners of gas. Moreover, these plants should respect national environmental legislation not exceeding at the stack more than 0.1mg/Nm^3 for total PAH. For this pollutant the relevant notation key NE has been used.

No PM emission factors are provided in the EMEP/EEA Guidebook for these activities, so after checking with the relevant industries the values of the EFs have been differentiated for the activities concerned with PM10 assumed as 80% of TSP and PM2.5 set equal to 60% of TSP (as suggested in the 2023 EMEP/EEA Guidebook, 2B Chemical industry, paragraph 3.2.2, pag.14).

Table 5.3 EF and emissions for PM2.5 from Chemical products 2D3g, 1990-2023.

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
EF PM10 polyester proc. [g PM10/Mg]	92	92	92	92	92	92	92	92	92	92
EF PM10 polyvinylchloride proc. [g PM10/Mg]	24.0	20.8	9.2	8.8	8.8	8.8	8.8	8.8	8.8	8.8
EF PM2.5 polyester proc. [g PM2.5/Mg]	69	69	69	69	69	69	69	69	69	69

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
EF PM2.5 polyvinylchloride proc. [g PM2.5/Mg]	18	15.6	6.9	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Total PM10 emissions [Gg]	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total PM2.5 emissions [Gg]	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

5.2.9 Other product use (2D3i)

The category includes NMVOC emissions from the application of glues and adhesives, which account for most of emissions from the category, emissions from fat, edible and non-edible oil extraction and minor emissions from glass wool enduction.

Activity data and emission factors for the application of glues and adhesives had been provided by the relevant industrial association up to 2004. After that period, activity data have been updated on the basis of information by ISTAT (ISTAT, several years) whereas the emission factor is considered constant in absence of further information.

For fat, edible and non-edible oil extraction activity data derive from the FAOSTAT database (http://faostat.fao.org) (FAO, several years) whereas default NMVOC emission factors do not change over the period and are equal to 1.57 g/kg seeds. PM emissions are also estimated in this category.

5.3 TIME SERIES AND KEY CATEGORIES

The sector accounts, in 2023, for about 44.1% of total national NMVOC emissions. PM10 and PM2.5 account for 3.2% and 2.2%, respectively. PAH emissions are also estimated in this sector but they account for about 1%.

NMVOC emissions from the use of solvent decreased from 1990 to 2023 of about 39.3%, from 633.1 Gg in 1990 to 384.3 Gg in 2023, mainly due to the reduction of emissions in paint application, in other use of solvent and in degreasing and dry cleaning activities. The general reduction observed in the emission trend of the sector is due to the implementation of the European Directive 1999/13/EC (EC, 1999) on the limitation of emissions of volatile organic compounds due to the use of organic solvents, entered into force in Italy in January 2004, and the European Directive 2004/42/EC (EC, 2004), entered into force in Italy in March 2006, which establishes a reduction of the solvent content in products. Moreover, the reduction of emissions from paint application, is also due to the implementation of the Italian Legislative Decree 161/2006. Figure 5.2 shows emission trends from 1991 to 2023 with respect to 1990 by sub-sector. The main source of emissions is domestic solvent use (2D3a), mostly for the consumption of cosmetics and cleaning products. The second source is paint application (2D3d) where NMVOC emissions derive mainly from the categories other industrial paint application and construction and buildings., followed by chemical products and other product use (2D3g), especially for emissions deriving from polyurethane processing, pharmaceutical products and paints manufacturing and leather tanning.

Figure 5.2 Trend of NMVOC emissions from 1991 to 2023 as compared to 1990

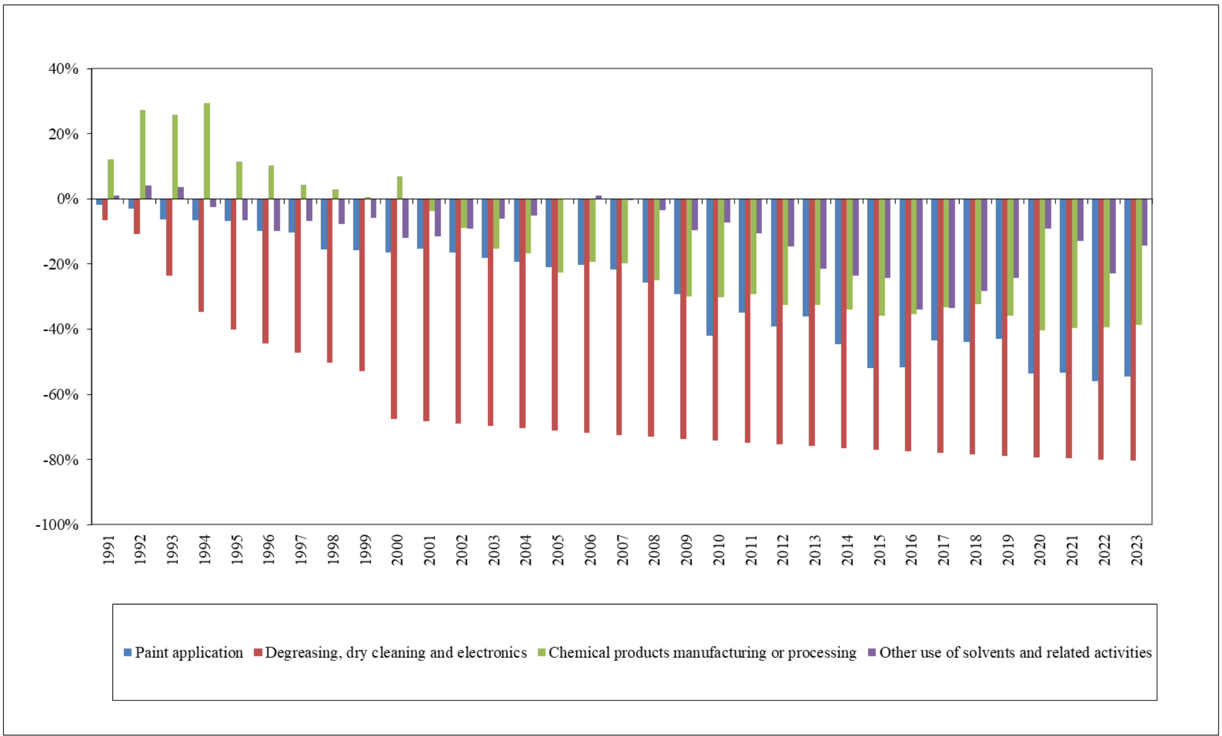


Table 5.4 represents the pollutants estimated in the sector and the key categories identified.

Table 5.4 Key categories in the IPPU - Solvent and other product use sector in 2023

	2D3a	2D3b	2D3c	2D3d	2D3e	2D3f	2D3g	2D3h	2D3i
SO_x									
NO_x									
NH_3									
NMVOC	17.68	0.06	0.001	14.10	0.69	0.35	5.43	2.01	3.79
CO			0.0003						
PM10		1.04	0.03				0.004		2.14
PM2.5		0.20	0.01				0.005		2.03
BC		0.09	0.00001						
PAH									0.02

Note: key categories are shaded in blue

In Table 5.5 and Table 5.6 activity data and emission factors used to estimate emissions from the sector are reported at SNAP code level.

A strong decrease in the content of solvents in the products in the nineties is observed.

Table 5.5 Activity data in the IPPU - Solvent and other product use sector

		1990	1995	2000	2005	2010	2015	2019	2020	2021	2022	2023
Paint application												
Paint application : manufacture of automobiles	*vehicles*	2,865,857	2,521,355	2,770,104	1,766,930	1,310,425	1,325,327	1,271,513	1,098,011	1,170,207	1,213,030	1,318,581
Paint application : car repairing	*Mg paint*	22,250	17,850	24,276	23,475	19,479	25,395	37,416	16,899	9,873	13,492	9,409
Paint application : construction and buildings (except item 06.01.07	*Mg paint*	111,644	120,736	125,928	163,455	168,358	158,661	196,105	177,383	178,811	180,873	171,830
Paint application : domestic use (except 06.01.07)	*Mg paint*	420,000	420,000	420,000	420,000	420,000	420,000	420,000	420,000	420,000	420,000	420,000
Paint application : coil coating	*Mg paint*	14,500	14,500	14,500	14,500	14,500	14,500	14,500	14,500	14,500	14,500	14,500
Paint application : boat building	*Mg paint*	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Paint application : wood	*Mg paint*	150,000	150,000	140,000	140,000	123,250	80,000	75,000	70,000	65,000	67,000	72,561
Other industrial paint application	*Mg paint*	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000	125,000
Degreasing, dry cleaning and electronics												
Metal degreasing	*Mg solvents*	52,758	32,775	25,895	22,237	19,095	16,398	14,517	14,081	13,659	13,249	13,117
Dry cleaning	*machines*	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Chemical products manufacturing or processing												
Polyester processing	*Mg product*	179,852	197,882	168,704	112,188	89,638	94,389	101,045	101,571	102,925	100,580	95,344
Polyvinylchloride processing	*Mg product*	617,600	575,600	405,285	348,497	0	0	0	0	0	0	0
Polyurethane processing	*Mg product*	145,700	230,633	350,187	175,278	247,350	245,460	231,545	240,631	235,007	229,757	248,565
Polystyrene foam processing (c)	*Mg product*	85,004	80,400	90,200	35,200	33,692	46,800	51,600	42,600	57,400	47,600	48,800
Rubber processing	*Mg product*	671,706	700,859	810,124	831,187	607,667	545,989	603,318	622,427	609,324	545,989	542,167
Pharmaceutical products manufacturing	*Mg product*	80,068	88,094	104,468	106,861	110,183	120,907	136,202	135,174	134,933	146,298	155,971
Paints manufacturing	*Mg product*	697,129	747,417	900,683	964,631	891,882	851,450	885,576	943,407	959,584	970,653	922,121
Inks manufacturing	*Mg product*	87,527	110,667	132,256	132,521	133,979	108,600	112,953	120,329	122,393	123,805	117,614
Glues manufacturing	*Mg product*	111,683	266,169	302,087	331,770	317,560	249,152	286,629	276,060	280,794	249,152	310,194
Asphalt blowing	*Mg product*	77,248	70,336	77,408	88,896	65,000	25,000	18,000	16,000	17,000	12,000	10,000
Textile finishing	*1000 m2*	1,332,679	1,301,105	1,173,047	987,705	831,236	631,573	543,469	518,522	569,048	517,890	473,680
Leather tanning	*1000 m2*	173,700	183,839	200,115	157,891	136,982	123,643	116,324	97,284	110,125	111,000	99,400
Other use of solvents and related activities												
Glass wool enduction	*Mg product*	105,029	119,120	139,421	129,958	115,332	86,929	99,552	88,319	105,574	104,898	82,915
Mineral wool enduction	*Mg product*	0	11,000	18,000	20,500	0	0	0	0	0	0	0
Printing industry	*Mg ink*	73,754	91,667	100,690	111,550	98,206	79,604	96,424	102,721	104,483	105,688	100,403
Fat, edible and non edible oil extraction	*Mg product*	3,476,760	3,655,506	3,100,397	3,669,261	3,469,017	3,088,122	4,436,953	4,487,458	4,365,373	4,208,823	4,689,885
Application of glues and adhesives	*Mg product*	98,500	234,751	266,996	292,687	280,150	219,801	252,863	243,540	247,716	219,801	273,652
Preservation of wood	*Mg product*	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000	9,000
Domestic solvent use (other than paint application)(k)	*Mg product*	1,938,779	2,282,020	2,470,538	2,831,001	2,682,920	2,335,160	2,422,579	2,516,905	2,710,626	2,822,009	3,026,723
Vehicles dewaxing	*vehicles*	2,540,597	1,740,212	2,361,075	2,238,344	1,972,070	1,594,259	1,949,554	1,441,385	1,519,936	1,336,310	1,581,678

Table 5.6 Emission factors in the IPPU - Solvent and other product use sector

			1990	1995	2000	2005	2010	2015	2019	2020	2021	2022	2023
06 01	**Paint application**												
06 01 01	Paint application : manufacture of automobiles	*g/vehicles*	8,676	6,296	4,833	4,065	2,854	3,037	2,614	2,685	2,455	2,111	2,149
06 01 02	Paint application : car repairing	*g/Mg paint*	700,000	700,000	605,500	605,500	497,810	617,377	527,187	434,596	526,266	479,153	589,320
06 01 03	Paint application : construction and buildings (except item 06.01.07)	*g/Mg paint*	300,000	300,000	300,000	300,000	200,000	152,412	209,310	184,193	198,007	166,326	178,501
06 01 04	Paint application : domestic use (except 06.01.07)	*g/Mg paint*	126,450	113,100	99,750	99,750	67,710	54,360	72,516	62,370	66,375	58,365	62,370
06 01 05	Paint application : coil coating	*g/Mg paint*	200,000	200,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
06 01 06	Paint application : boat building	*g/Mg paint*	750,000	750,000	622,500	475,417	340,000	340,000	340,000	340,000	340,000	340,000	340,000
06 01 07	Paint application : wood	*g/Mg paint*	446,500	425,000	406,300	390,750	377,250	354,000	333,250	313,750	313,750	313,750	313,750
	Other industrial paint application	*g/Mg paint*	530,000	530,000	439,900	337,583	250,000	250,000	250,000	250,000	250,000	250,000	250,000
06 02	**Degreasing, dry cleaning and electronics**												
06 02 01	Metal degreasing	*g/Mg solvents*	700,000	700,000	460,000	460,000	460,000	460,000	460,000	460,000	460,000	460,000	460,000
06 02 02	Dry cleaning	*g/machines*	306,000	154,000	103,000	103,000	103,000	103,000	103,000	103,000	103,000	103,000	103,000
06 03	**Chemical products manufacturing or processing**												
06 03 01	Polyester processing	*g/Mg product*	325	325	325	325	325	325	325	325	325	325	325
06 03 02	Polyvinylchloride processing	*g/Mg product*	0	0	0	0	0	0	0	0	0	0	0
06 03 03	Polyurethane processing	*g/Mg product*	120,000	110,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
06 03 04	Polystyrene foam processing (c)	*g/Mg product*	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000	60,000
06 03 05	Rubber processing	*g/Mg product*	12,500	10,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
06 03 06	Pharmaceutical products manufacturing	*g/Mg product*	55,000	55,000	55,000	55,000	55,000	55,000	55,000	55,000	55,000	55,000	55,000
06 03 07	Paints manufacturing	*g/Mg product*	15,000	15,000	15,000	13,110	10,863	9,524	10,769	8,230	8,100	7,538	8,257
06 03 08	Inks manufacturing	*g/Mg product*	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
06 03 09	Glues manufacturing	*g/Mg product*	20,000	5,041	3,603	2,806	2,806	2,806	2,806	2,806	2,806	2,806	2,806
06 03 10	Asphalt blowing	*g/Mg product*	544	544	544	544	544	544	544	544	544	544	544
06 03 12	Textile finishing	*g/1000 m2*	296	296	296	296	296	296	296	296	296	296	296
06 03 13	Leather tanning	*g/1000 m2*	150,000	150,000	125,000	105,378	82,267	71,000	54,100	44,000	39,000	52,000	44,000
06 04	**Other use of solvents and related activities**												
06 04 01	Glass wool enduction	*g/Mg product*	800	800	800	800	800	800	800	800	800	800	800
06 04 02	Mineral wool enduction	*g/Mg product*	300	300	300	300	300	300	300	300	300	300	300
06 04 03	Printing industry	*g/Mg ink*	234,649	228,190	184,332	174,227	174,227	174,227	174,227	174,227	174,227	174,227	174,227
06 04 04	Fat, edible and non edible oil extraction	*g/Mg product*	1,570	1,570	1,570	1,570	1,570	1,570	1,570	1,570	1,570	1,570	1,570
06 04 05	Application of glues and adhesives	*g/Mg product*	600,000	151,230	108,086	84,190	84,190	84,190	84,190	84,190	84,190	84,190	84,190
06 04 06	Preservation of wood	*g/Mg product*	105,000	105,000	105,000	105,000	105,000	105,000	105,000	105,000	105,000	105,000	105,000
06 04 08	Domestic solvent use (other than paint application)(k)	*g/Mg product*	78,934	69,270	62,291	65,228	64,121	60,263	54,626	67,109	58,637	48,842	50,874
06 04 09	Vehicles dewaxing	*g/vehicles*	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

5.4 QA/QC AND VERIFICATION

Data production and consumption time series for some activities (paint application in constructions and buildings, polyester processing, polyurethane processing, pharmaceutical products, paints manufacturing, glues manufacturing, textile finishing, leather tanning, fat edible and non-edible oil extraction, application of glues and adhesives) are checked with data acquired by the National Statistics Institute (ISTAT, several years), the Sectoral Association of the Italian Federation of the Chemical Industry (AVISA, several years) and the Food and Agriculture Organization of the United Nations (FAO, several years). For specific categories, emission factors and emissions are also shared with the relevant industrial associations; this is particularly the case of paint application for wood, some chemical processes and anaesthesia and aerosol cans.

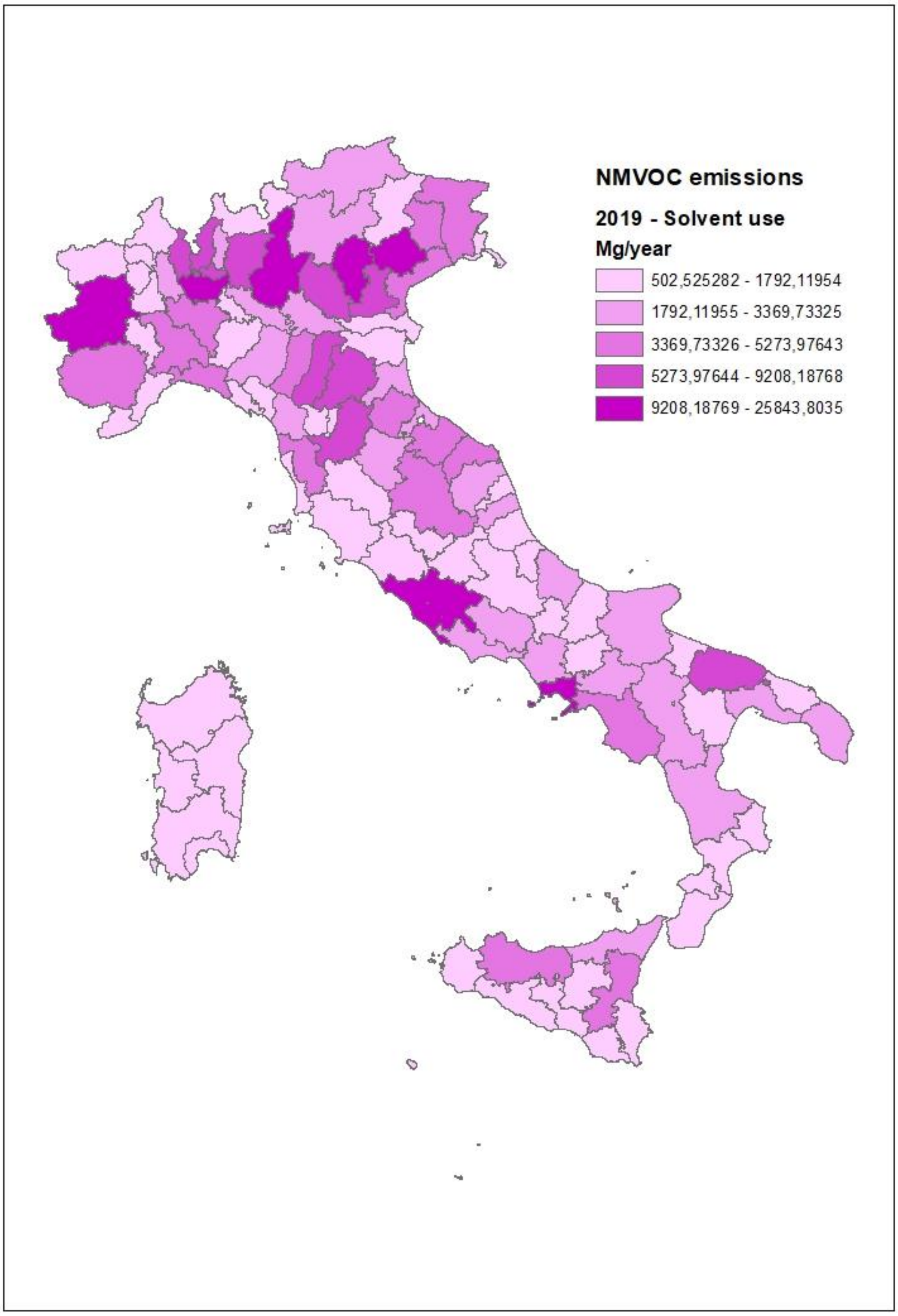
In addition, for paint application, data communicated from the industries in the framework of the EU Directive 2004/42, implemented by the Italian Legislative Decree 161/2006, on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products have been used as a verification of emission estimates. These data refer to the composition of the total amount of paints and varnishes (water and solvent contents) in different subcategories for interior and exterior use and the total amount of products used for vehicle refinishing and they are available from the year 2007.

Inventory estimates are also checked against ESIG data showing quite good results at the total level, but it is not always possible to use ESIG data to update national emission factors at the category level. For instance, based on new ethanol data provided by ESIG, Italy has further examined the use of hand sanitizers for this year submission improving the relevant emission estimates.

Furthermore, every five years (for inventory years from 1990 to 2015) and every four years for inventory years from 2015 onwards ISPRA carries out emission estimates at NUTS level which is the occasion of an additional check with local environmental agencies.

The distribution of NMVOC emissions from the solvent and other product use sector at NUTS3 level for 2019 is reported in Figure 5.3; methodologies are described in the relevant publication (ISPRA, 2022).

Figure 5.3 NMVOC emissions from solvent and other product use in 2019 (t)



5.5 RECALCULATIONS

Recalculations occurred for different categories during this year's submission.

In paint application, a revision of activity data and emission factor for 2019 in the manufacture of automobile occurred. Emission factors were revised also for construction and buildings and domestic use for 2021 and 2022.

In response to the review process, and the use of the figures in the EMEP /EEA Guidebook 2023, the emission factor for metal degreasing was revised from 2000.

In chemical product processing and manufacturing, a recalculation occurred on account of a change in EFs for leather tanning for 2021 and activity data from 2008 due to information available from the industrial association reports.

Major recalculations affected the domestic solvent use category, where following the review recommendations, the use of hand sanitizers in Italy was further examined and a recalculation occurred both in activity data and emission factors, based on ethanol data provided by a study by ESIG and TNO.

5.6 PLANNED IMPROVEMENTS

Specific developments will regard the improvement of emission factors for some relevant categories. In particular, several improvements are planned with the aim of updating the status of technologies in this sector where main challenges regard the availability of data collected from the industry.

Following the review process, a focus will be on other industrial paint applications where the activity data used in the national inventory do not seem to be included in the guidebook (products from mechanical industries other than vehicles).

Also, the inclusion of emissions from the aircraft de-icing activity as part of category 2D3i needs further exploration because no data is currently available to estimate these emissions at national level.

6 AGRICULTURE (NFR SECTOR 3)

6.1 OVERVIEW OF THE SECTOR

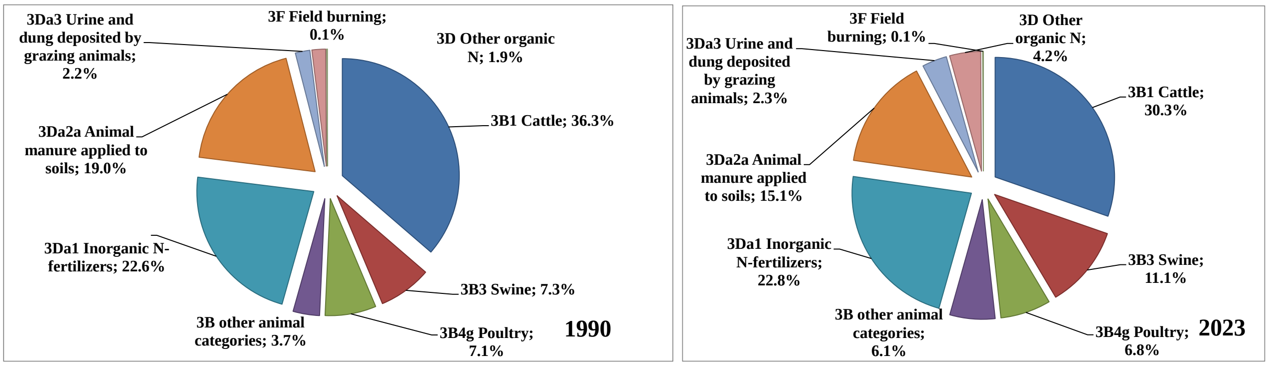
The agriculture sector is responsible for the largest part of NH_3 emissions, and contributes also to PM10, PM2.5, BC, TSP, NOX, NMVOC, CO, SO_2, heavy metals (As, Cr, Cu, Ni, Se, Zn, Pb, Cd, Hg), Dioxins, PAH and HCB emissions. Italy estimates agricultural emissions for manure management (3B), agricultural soils (3D) including the use of pesticides, and field burning of agricultural wastes (3F). NO_X emissions are reported as NO_2.

In 2023, key categories level was identified for NH_3 emissions (3B1a, 3B1b, 3B3, 3B4gii, 3Da1, 3Da2a and 3Da3), for NMVOC emissions (3B1a and 3B1b), for PM10 emissions (3Dc) and NOx emissions (3Da1). In 1990 similar figures were obtained except for NH_3 emissions 3B4gii and 3Da3 and for NOx emissions 3Da1 which were not key categories. In addition, HCB emissions 3Df and PM10 emissions 3B4gii were key categories. For the trend analysis, key categories were related to NH_3 emissions (3B1a, 3B1b, 3B3, 3B4a, 3Da2a, 3Da2c and 3Da3), NOx emissions (3Da1 and 3Da2a), NMVOC emissions (3B1a and 3B1b), PM10 emissions (3Dc) and HCB (3Df).

In 2023, NH_3 emissions from the agriculture sector were 349.2 Gg (91.4% of national emissions) where 3B, 3D and 3F categories represent 49.7%, 41.6% and 0.1% of total national emissions. The trend of NH_3 from 1990 to 2023 shows a 30.1% decrease due to the reduction in the number of animals, the diffusion of best environmental practices in manure management in relation to housing, storage and land spreading systems, the decrease of cultivated surface/crop production and use of N-fertilisers.

A representation of the contribution by source of agriculture NH_3 emissions for 1990 and 2023 is shown in Figure 6.1.

Figure 6.1 Share of NH_3 emissions in the agriculture sector for 1990 and 2023.



Agricultural official statistics are mainly collected from the National Institute of Statistics, ISTAT. Most important activity data (number of animals, N-fertilizers, agricultural surface and production, milk production) are available on-line: http://dati.istat.it/. ISTAT has a major role in the comprehensive collection of data through structural (such as the Farm Structure Survey, FSS) and conjunctural surveys, and the general agricultural census[1]. For consistency reasons the same agricultural official statistics are used for UNFCCC and UNECE/CLRTAP emission inventory. ISPRA participates in the Agriculture, Forestry, and Fishing Quality Panel, which has been established to monitor and improve national statistics. This is the opportunity to get in touch with experts from the Agriculture Service from ISTAT in charge of main agricultural surveys. In this way, data used for the inventory is continuously updated according to the latest information available. Agricultural statistics reported by ISTAT are also published in the European

1 The last census was conducted in 2021 (which surveyed data from the 2019/2020 crop year and livestock raised as of December 1, 2020) and the first results are available at the link https://www.istat.it/it/archivio/273753. Micro-data were released in January 2024.

statistics database[2] (EUROSTAT). The verification of statistics is part of the QA/QC procedures; therefore, as soon as outliers are identified ISTAT and category associations are contacted. In Table 6.1 the time series of animal categories is shown.

Table 6.1 Time series of animals

Year	Dairy cattle	Non-dairy cattle	Buffalo	Sheep	Goats	Horses	Mules/ asses	Swine	Rabbits	Poultry	Fur animals
						heads					
1990	2,641,755	5,110,397	94,500	8,739,253	1,258,962	287,847	83,853	8,406,521	14,893,771	173,341,562	325,121
1995	2,079,783	5,189,304	148,404	10,667,971	1,372,937	314,778	37,844	8,060,676	17,110,587	184,202,416	220,000
2000	2,065,000	4,988,000	192,000	11,089,000	1,375,000	280,000	33,000	8,307,000	17,873,993	176,722,211	230,000
2005	1,842,004	4,409,921	205,093	7,954,167	945,895	278,471	30,254	9,200,270	20,504,282	174,667,361	200,000
2010	1,746,140	4,086,317	365,086	7,900,016	982,918	373,324	46,475	9,321,119	17,957,421	175,912,339	125,000
2015	1,826,484	3,954,864	374,458	7,148,534	961,676	384,767	70,872	8,674,793	15,760,502	177,391,671	180,000
2020	1,638,382	4,354,633	407,027	7,034,164	1,065,712	367,561	72,455	8,543,029	11,010,203	179,328,828	50,000
2021	1,609,948	4,260,926	409,408	6,728,351	1,060,748	367,561	72,455	8,407,968	10,945,940	176,805,847	20,000
2022	1,631,128	4,001,608	416,053	6,567,546	1,010,143	365,414	75,978	8,739,384	12,674,189	165,302,265	20,000
2023	1,574,406	4,007,697	416,479	6,497,003	979,913	365,414	75,978	9,171,160	13,699,361	173,372,163	20,000

As for poultry, since no annual statistics on the number of animals are available, the following methodology was followed. For 1990 the ISTAT data from the Agricultural Census have been used; for the years 1991-1999, the number of heads was estimated on the basis of the annual decreases/increases in the production of heads and meat supplied by UNA (National Union of Poultry, which later became UNAITALIA); for 2000 and 2010 ISTAT data from the Censuses of Agriculture for laying hens and broilers were used; for the period 2001-2009 and since 2011 data on the number of broilers and laying hens have been updated, as described below; for the other poultry category, since 1998 the data have been estimated on the basis of UNAITALIA data. Data on turkeys derive from the ISTAT statistics on the Census and the FSS survey.

As stated, data on the number of broilers and laying hens in the period 2001-2009 and since 2011 have been updated. The estimation methodology involved successive steps. Firstly, ISTAT data from the Census and FSS surveys (available for the years 2000, 2005, 2007, 2010, 2013, 2016 and 2020) were considered; on the basis of these data the number of heads was estimated for the missing years from 2001, assuming a linear trend. The second step involved estimating the number of animals since 2001 based on production data provided by UNAITALIA. The annual variation in production was multiplied by the number of animals in the 2000 Census. The third step was to calculate the average of the two time series calculated in the previous steps.

In Table 6.2 the nitrogen content of N-fertilisers by type applied to soils is shown together with the differentiated EFs. Detailed figures for "other nitrogenous fertilizers" are reported from 1998 because disaggregated official statistics from ISTAT were available only from that year.

2 http://ec.europa.eu/eurostat/data/database

Table 6.2 Time series of N content by fertilisers and relevant emission factors

Type of fertilizers	Emission factor % of N applied	Emission factor g NH_3/kg N applied	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
			Nitrogen content (t N yr^{-1})									
Ammonium sulphate	12.55 %	152.42	50,762	61,059	36,698	27,855	32,568	16,986	17,830	22,963	14,261	31,380
Calcium cyanamide	3.51 %	42.60	3,310	507	3,003	2,357	4,958	3,046	2,845	2,845	2,628	2,629
Nitrate (*)	6.45%	78.33	46,657	52,769	48,701	58,427	32,964	40,157	28,097	23,786	15,543	19,700
CAN	3.51 %	42.60	112,565	139,253	112,541	109,445	71,261	51,200	55,339	57,134	31,797	31,430
Urea	16.66 %	202.31	291,581	321,196	329,496	317,814	209,829	266,154	295,134	240,692	135,156	265,710
Other nitric nitrogen	3.51 %	42.60	-	-	3,204	5,219	3,332	1,189	2,155	1,012	2,224	2,900
Other ammoniacal nitrogen	3.51 %	42.60	-	-	6,278	18,069	12,412	7,035	9,036	10,480	6,415	9,563
Other amidic nitrogenous	16.66 %	202.31	-	-	6,988	17,420	15,366	11,796	29,366	43,075	13,394	19,475
Phosphate nitrogen	12.55 %	152.42	112,237	99,468	77,916	69,758	45,837	35,054	44,533	43,410	19,983	35,791
Potassium nitrogen	4.28 %	52.00	3,937	2,876	5,291	12,289	15,955	9,077	11,353	11,169	7,181	7,111
NPK nitrogen	12.55 %	152.42	138,018	101,528	113,897	106,384	64,462	50,174	45,730	53,190	28,166	46,029
Organic mineral	3.51 %	42.60	444	20,960	38,688	34,809	19,085	25,986	36,033	29,137	23,040	21,937
Total			**759,510**	**799,614**	**782,701**	**779,846**	**528,029**	**517,854**	**577,451**	**538,893**	**299,788**	**493,655**

(*) includes ammonium nitrate < 27% and ammonium nitrate > 27% and calcium nitrate. The emission factor g NH3/kg N applied is a weighted average of factors 42.60 and 152.42 g NH3/kg N applied of ammonium nitrate and calcium nitrate.

6.2 METHODOLOGICAL ISSUES

Methodologies used for estimating national emissions from this sector are based on and conform to the EMEP/EEA Guidebook (EMEP/EEA, 2023) and the IPCC Guidelines (IPCC, 1997; IPCC, 2006). Consistency among methodologies for the preparation of the agricultural emission inventory under the UNFCCC and UNECE/CLRTAP is guaranteed through an operational synergy for activity data collection, inventory preparation and reporting to international conventions and European Directives. Information reported in the National Inventory Document/Common Reporting Table (NID/CRT) for the GHG inventory is coherent and consistent with information reported in the Informative Inventory Report/Nomenclature for Reporting (IIR/NFR).

Factor 1.214 (= 17/14) was used to convert ammonia nitrogen (N-NH_3) to ammonia (NH_3) and factor 3.286 (= 46/14) was used to convert the nitrogen form (N-NO) to nitrogen dioxide (NO_2).

6.2.1 Manure management (3B)

For 3B category, Italy has estimated emissions for pollutants recommended in the 2023 EMEP/EEA Guidebook (NH_3, NO_X, NMVOC, PM10 and PM2.5). A detailed and updated description of the methodologies for the estimation of NH_3 emissions, as well as of national specific circumstances and reference material, is provided in the NIR (ISPRA, several years [a]). Detailed information on activity data sources, methods and EFs by pollutant for 3B category is shown in Table 6.3.

Table 6.3 Activity data sources, methods and emission factors by pollutant for manure management.

NFR code	Animal category	Method	Activity data	Emission Factor
3B1a, 3B1b	Cattle	T2 (NH_3, NO_x, NMVOC), T1 (PM10, PM2.5)	NS	CS (NH_3, NO_x), D (PM10, PM2.5), T2 (NMVOC)
3B4a, 3B2, 3B4d, 3B4e, 3B4f	Buffalo, Sheep, Goats, Horses, Mules and Asses	T2 (NH_3, NO_x, NMVOC), T1 (PM10, PM2.5)	NS, IS	CS (NH_3, NO_x), D (PM10, PM2.5), T2 (NMVOC)
3B3	Swine	T2 (NH_3, NO_x, NMVOC), T1 (PM10, PM2.5)	NS	CS (NH_3, NO_x), D (PM10, PM2.5), T2 (NMVOC)
3B4gi, 3B4gii,3B4 giii 3B4giv	Poultry	T2 (NH_3, NO_x, NMVOC), T1 (PM10, PM2.5)	AS	CS (NH_3, NO_x), D (PM10, PM2.5), T2 (NMVOC)
3B4h	Other	T2 (NH_3, NO_x, NMVOC), T1 (PM10, PM2.5)	NS	CS (NH_3, NO_x), D (PM10, PM2.5), T2 (NMVOC)

NS=national statistics; IS= International statistics (FAO); AS= category association statistics (UNAITALIA); CS=country-specific; D=Default (from EMEP/EEA Guidebook)

Concerning the 3B category, the estimation procedure for NH_3 emissions consists in successive subtractions from the quantification of nitrogen excreted annually for each livestock category. This quantity can be divided into two different fluxes, depending on whether animals are inside (housing, storage and manure application) or outside the stable (grazing). More in detail, the proportion of nitrogen excreted within the shelter undergoes losses through volatilization already during the manure's stay within the breeding premises. These losses are calculated with the emission factors for emissions from housing for different livestock categories; this amount of nitrogen lost is therefore subtracted from the total nitrogen excreted to obtain the amount of nitrogen for storage. During storage another fraction of nitrogen is lost (calculated with the relevant emission factor for storage), which is then subtracted to obtain the amount of nitrogen available for the agronomic spreading. Losses occurring during the spreading are finally calculated with the specific emission factor for spreading. For the nitrogen excreted in the pasture losses due to volatilization calculated with the relevant emission factor for grazing by livestock only occur at this stage (CRPA, 2006[a]).

The manure application source is reported in 3Da2a Animal manure applied to soils and the animal grazing source is reported in 3Da3 Urine and dung deposited by grazing animals. As regards the animal grazing, the percentage of grazing animals is equal to (CRPA, 1997, CRPA, 2006[a], ISTAT 2020 Agricultural Census): in 1990, 5% for dairy cattle, 2.2% for non-dairy cattle, 2.9% for buffalo, 60% for equines, 90% for sheep and goats; in 2023, 6.8% for dairy cattle, 19.3% for non-dairy cattle. The excretion rates, slurry/solid manure production and average weights are derived from country specific information (CRPA, 2018; CRPA, 2006[a]; GU, 2006; Xiccato et al., 2005; Regione Emilia Romagna, 2004). Other improvements of country specific EFs were obtained with research studies (CRPA, 2010[b]; CRPA, 2006[a], [b]; CRPA, 2000). Average weight and N excretion rate for NH_3 estimations are reported in Table 6.4.

Table 6.4 Average weight and nitrogen excretion rates from livestock categories in 2023

Category	Weight kg	Housing	Grazing kg N head-1 yr-1	Total
Non-dairy cattle	392.2	41.58	9.94	**51.53**
Dairy cattle	602.7	106.11	7.76	**113.87**
Buffalo	493.5	57.16	1.71	**58.87**
Other swine (*)	86.7	13.24	-	**13.24**
Sow (*)	172.1	28.62	-	**28.62**
Sheep	48.1	1.62	14.58	**16.20**

Category	Weight kg	Housing	Grazing kg N head-1 yr-1	Total
Goats	49.3	1.62	14.58	**16.20**
Horses	550.0	20.00	30.00	**50.00**
Mules and asses	300.0	20.00	30.00	**50.00**
Poultry	1.6	0.45	-	**0.45**
Rabbit	1.6	1.02	-	**1.02**
Fur animals	1.0	4.10	-	**4.10**

(*) Other swine and sows are sources that represent the 'swine' category

6.2.1.1 Dairy cattle (3B1a)

Following the update of the gross energy intake (GE), based on the estimation of the parameter digestibility (DE) of diet, the excreted nitrogen value of dairy cows was updated for the whole time series. Excreted nitrogen is in fact calculated from GE using equations 10.31-10.33 of the 2006 IPCC Guidelines. In addition, the percentage for protein in diet has been updated from the previous submission. This parameter is used with GE in the estimation of excreted nitrogen.

As regards the DE parameter, the estimation methodology, set out in the 2019 IPCC Guidelines, allows, from data on average annual milk production per cow and per production level (low "<5000 kg/head/year", medium "5000-8500 kg/head/year" and high ">8500 kg/head/year") and information on animal diets, to calculate an average value of DE and Ym for dairy cows. Based on data from the Italian Livestock Breeders' Association (AIA) on average annual milk production and the number of dairy cows in production, by region and breed, the distribution of animals was calculated according to the three productivity levels identified by the 2019 IPCC Guidelines, for the years 2004-2019. The AIA carries out milk productivity checks on behalf of the Ministry of Agriculture and each year the sample of animals checked is about 50% of the number of animals raised. The difference in dairy cow numbers between the AIA total and the ISTAT total (used for emission estimates) was attributed to the low production level. The DE values assigned to the three production levels (low, medium, high) are 62, 65 and 70.11 respectively and were identified in collaboration with the CRPA dairy cow feeding experts. The value 62 is the minimum value of the range indicated in Table 10.12 for low producing cows. The value 65 is lower than the average value of the range indicated in Table 10.12 for medium producing cows. The value 70.11 for high-producing cows is a weighted average of two values: the first is 65 (corresponding to diets with DE≥70 and NDF≥35) and was attributed to 27% of the high-producing cows fed without silage fodder; the second is 72 (corresponding to diets with DE≥70 and NDF≤35) and was attributed to 73% (=100-27%) of the high-producing cows fed silage fodder. With reference to the 27% of cows, this value includes cows whose milk is intended to produce Parmigiano Reggiano (17% of total cows), and cows fed with good quality dry and green fodder (e.g. for the production of Trentingrana PDO (Protected Designation of Origin), Latte Fieno STG (Traditional Speciality Guaranteed) and other mountain cheeses; 10% of total cows). In support of the choices made for high productivity values, mention is made of a study published in 2020 (Gislon et al, 2020) carried out on eight Italian Friesian cows in multiparous lactation, with high productivity, using a 4 × 4 replicated Latin square pattern. The experimental design of the square involves all cows receiving all diets (with adaptation periods between each), so we have 2 groups of 4 cows that rotated 4 times on as many diets. The number of observations for each diet is 32. The cow effect is nullified because they all receive all diets and the results obtained are therefore irrefutable and highly representative, according to CRPA experts. Four diets, based on the following forages (% of dry matter, DM; neutral detergent fiber content, NDF, expressed as % of DM), were tested: corn silage (CS, 49.3; 32.8 NDF), alfalfa silage (AS, 26.8; 27.1 NDF), wheat silage (WS, 20.0; 33.7 NDF), and a typical hay-based Parmigiano Reggiano cheese production diet (PR, 25.3 of both alfalfa and Italian ryegrass hay; 36.7 NDF). The lowest DM digestibility was observed for the PR diet (64.5%) and the highest for the CS diet (73.3%); AS and WS diets showed intermediate values (71.4 and 70.3% respectively). PR diet is associated with diets with DE≥70 and NDF≥35 in table 10.12 of the 2019 IPCC Guidelines and the other three diets are associated with diets with DE≥70 and NDF≤35 in the same table. For the year 2023, the percentages of dairy cows according to the three productivity levels (high, medium and low) are 81.4%, 10.8% and 7.8%. The digestibility values associated with these productivity levels are, as mentioned earlier, 70.11%, 65% and 62% respectively. With these data, the average digestibility value of the diets consumed by dairy cows was calculated as 68.92%. As regards the percentage for protein in diet, mentioned above, based on data from around 500 samples of rations (unifeed) of lactating and dry dairy cows, analysed by the CRPA's zootechnical feed service for the three-year period 2017-2019, from all over Italy, the crude protein of the ration was updated. The data were obtained by weighing the values expressed as % of the dry matter of the ration with the average annual lactation period (equal to 305 days) and the dry period (equal to 60 days). The value obtained, 14.22, was used for the time series from 2010 onwards, as indicated by the CRPA experts. For the previous years, the previous figure of 15.32 was left until 2000, and an average value of 14.5 was used for the intermediate years between 2000 and 2010.

In Table 6.5 the animal waste management system (AWMS) distribution and EFs used for the dairy cattle category are reported. For 2014-2023, for dairy cattle emissions were used data reported in Table 6.5 and specifically for housing data from 2010 and for storage, data from 2013. EF was multiplied by the percentage of the nitrogen excreted in housing equal to 93.2% of the total, assuming that 6.8% is excreted in grazing, in 2023. The EF is a weighted average based on country specific emission factors for different livestock housing and the distribution of animals in shelters which has been assumed in the following main housing systems reported in Table 6.5 (based on a 1998 CRPA survey carried out in Lombardy, Emilia Romagna and the center of Italy and on ISTAT statistics of 2003 and on 2010 and 2020 Agricultural Census). For the period 2005-2010 and 2010-2020 a gradual transition to the updated distribution of housing systems has been assumed for the intermediate years considering the gradual penetration of systems to ensure animal welfare.

Table 6.5 AWMS distribution and EF by manure management system for the dairy cattle category

Emission factors by manure management system	1990	2003	2005	2010	2013	2020
Housing						
cubicle house: 14.3 N-NH_3 kg/head/year (Bonazzi et al, 2005)	14.7%	14.7%	14.7%	27.9%	27.9%	41.4%
loose housing on bedding: 15.7 N-NH_3 kg/head/year (Bonazzi et al, 2005)	9.2%	9.2%	9.2%	42.6%	42.6%	34.4%
tied cows: 12.9 N-NH_3 kg/head/year (Bonazzi et al, 2005)	76.1%	76.1%	76.1%	29.5%	29.5%	24.2%
EF N-NH_3 kg/head/year	13.4	13.4	13.4	14.5	14.5	14.4
Storage						
liquid manure	liquid manure = 36.2%	liquid manure = 36.2%	liquid manure = 36.2%	liquid manure = 48.1%	liquid manure = 53.3%	liquid manure = 62.0%
tanks (for liquid manure): 23% of N at storage (Bonazzi et al, 2005)	40.0%	75.5%	75.5%	82.3%	70.1%	70.1%
lagoons (for liquid manure): 32.2% (multiplication factor equal to 1.4 respect to tanks)	50.0%	12.5%	12.5%	2.5%	1.7%	1.7%
covered storage (for liquid manure):	10.0%	12.5%	12.5%	15.2%	28.3%	28.2%
covered tanks high reduction: 4.6% (reduction of 80% compared to tanks)		1.0%	1.0%	3.0%	4.0%	0.8%
covered tanks medium reduction: 9.2% (reduction of 60% compared to tanks)		1.0%	1.0%	3.0%	4.0%	0.8%

Emission factors by manure management system	1990	2003	2005	2010	2013	2020
covered tanks low reduction: 13.8% (reduction of 40% compared to tanks)	10.0%	10.5%	10.5%	6.2%	5.5%	7.8%
Biogas with covered digestate tank: no emission				0.32%(1)	3.9%(1)	9.0%
Biogas with open digestate tank: 2.66% (EMEP/EEA, 2023)				2.68%	10.8%	9.8%
solid storage: 14.2% of N at storage (Regione Emilia Romagna, 2001)	solid manure = 63.8%	solid manure = 63.8%	solid manure = 63.8%	solid manure = 51.9%	solid manure = 46.7%	solid manure = 38.0%

(1) Data were calculated from the results of the CRPA study on assessing the emission effects of livestock processing (CRPA, 2018). The study estimated that in 2020 19% of cattle manure would be sent to anaerobic digestion and 48% of digestate tanks would be covered. Based on these results, it was assumed that: in 2010, 1% of manure went to digesters and 11% covered digestate tanks; in 2013 these values become 15% and 27%, respectively. This trend was assumed to be based on the exponential growth in the last ten years of anaerobic digesters.

As regards the manure storage (see Table 6.5), emission factors are expressed as a percentage of the nitrogen contained in manure to storage. Emission factors used for tanks are derived from national literature (Bonazzi et al, 2005) and emission factors for lagoons and covered storage have been estimated applying an increase (for lagoons) and a reduction (for covered storage) to tanks EF (as referenced in CRPA, 2006[a]; CRPA, 2006[b]).

The proportion of liquid system (considering liquid system= liquid system + digesters) and solid storage (considering solid storage= solid storage + digesters), reported in the CRT (Common Reporting Table for the GHG inventory) refer to the nitrogen excreted and not to the amount of animal waste. The proportion reported in the Table 6.5 refer to manure production according to the type of housing.

EFs for lagoons and covered storage have been provided by CRPA (CRPA, 2006[a]). For lagoons, they have a high exposure area relative to their capacity and represent a higher emission type than the tank. Considering the volumes of the two types of storage, an increase in the surface of slurry in the lagoons with respect to the tanks can be estimated equal to 40%. Since ammonia emissions are estimated to be proportional to the surface of slurry exposed to air, emissions from lagoons will be approximately 40% higher than those of the tanks (CRPA, 1997). For covered storage, the emission reduction has been assumed based on the ILF-BREF document (EC, 2003) and the Ammonia Guidance Document (Bittman S. et al, 2014), as reported in CRPA (CRPA, 2006[a]; 2018).

A linear emission reduction in the period 1990-2003 has been estimated to assess the dynamics of evolution of storage systems from the values available in 1990 and 2003, as reported by CRPA (CRPA, 2006[a]). In 2003, respect to 1990, an increase of storage in tanks with respect to lagoons as well as a small increase of covered storage is observed as available in the Table 6.5. Based on ISTAT statistics on storage systems as 2010 and 2020 Agricultural Census and 2013 Farm Structure Survey, an update of emission factors from manure storage for cattle category has been estimated. A gradual transition to the updated emission factors has been assumed for the intermediate years (for the period 2005-2010, 2010-2013 and 2013-2020) taking into account the gradual penetration of the abatement technologies.

Based on the study for the evaluation of the effects on emissions of livestock management practices carried out by CRPA for the emission scenarios for 2020 and 2030 (CRPA, 2018), NH_3 emissions from storage for cattle have been modified considering the average distribution of the covered tanks related to the different ammonia emission reduction efficiencies.

EFs for manure storage reported in the Table 6.5 have been multiplied by the percentage of nitrogen remaining after housing emissions and the result has been multiplied by the nitrogen excreted in housing to obtain emissions from storage. Emissions have been divided by total heads to obtain the EF kg/head reported in Table 6.8 for the year 2023.

Regarding emission factors for cattle, the evolution of different abatement technologies throughout the period is considered in the EFs used for NH_3 estimation for housing, storage and land spreading systems. Improvements in the abatement technologies are based on the results of both the IIASA questionnaire for the implementation of RAINS scenarios in 2003 and an ad hoc survey conduct in 2005 by CRPA (CRPA, 2006 [a], [b]) and on ISTAT statistics such as 2010 and 2020 Agricultural Census, 2013 and 2016 Farm Structure Survey.

6.2.1.2 *Swine (3B3)*

Activity data of swine population (3B3) reported in the IIR/NFR are different from data reported in the NIR/CRF. In fact, piglets (swine less than 20 kg) are included in the swine population in the NIR/CRF for the estimation of CH_4 emission from enteric fermentation, while they are not included in the number of the NFR templates because the NH_3 EF used for sows considers the emissions from piglets, thus ensuring the comparability of the implied emission factors. For NH_3 estimations average weighted emission factors for each category (other swine and sows) are calculated taking into account the relevant emission factors of the abatement technologies for each manure system.

The implemented abatement technologies for the years 1990, 2003, 2005, 2010, 2013, 2016 and 2020 are reported in Table 6.6. For 2014-2023, data reported in Table 6.6 for swine emissions were used. Specifically for housing, data from 2010, for the years 2014-2019, data from 2020, for year 2020 onwards were used; for storage, data from 2013, for the years 2014-2019, data from 2020, for year 2020 onwards were used; for spreading, data from 2013, for the years 2014-2015, data from 2016, for the years 2016-2019, data from 2020, for 2020 onwards, were used.

Table 6.6 Abatement technologies for the swine category

Livestock category	1990	2003	2005	2010	2013	2016	2020
Housing							
fattening swine	55% Partly-slatted floor (PSF);20% Fully-slatted floor (FSF);25% solid floor	55% PSF;25% FSF;20% solid floor	26% FSF (of which 6% solid floor);39% PSF;12% FSF + vacuum system (VS);4% FSF + with flush canals;7% FSF + with flush tubes;5% PSF + VS;6% PSF + with flush canals;1% PSF + with flush tubes	39% PSF;43% FSF;5% solid floor; 13% deep litter	Same distribution for the year 2010	Same distribution for the year 2010	33% PSF;50% FSF;13% solid floor; 3% deep litter
gestating sows (75% of the total sows)	65% FSF; 35% PSF	50% FSF; 50% PSF	26% FSF; 52% PSF; 5% FSF + vacuum system (VS); 5% FSF + with flush canals;7% FSF + with flush tubes; 2% PSF + VS; 2% PSF + with flush canals; 1% PSF + with flush tubes	39% PSF;43% FSF;5% solid floor; 13% deep litter	Same distribution for the year 2010	Same distribution for the year 2010	33% PSF;40% FSF;20% solid floor; 7% deep litter
lactating sows (25% of the total sows)	75% FSF+ deep collection pit; 25% sloping floor	65% FSF+ deep collection pit; 35% sloping floor	52% FSF + deep collection pit; 39% sloping floor; 3% with flush; 6% mechanical removal	39% PSF;43% FSF;5% solid floor; 13% deep litter	Same distribution for the year 2010	Same distribution for the year 2010	33% PSF;40% FSF;20% solid floor; 7% deep litter
weaners 6-20 kg	80% FSF + deep collection pit; 20% sloping floor	70% FSF+ deep collection pit; 30% sloping floor	63% FSF + deep collection pit; 14% sloping floor; 7% FSF + VS; 11% FSF with flush tubes; 2% FSF + scraper; 2% PSF + VS; 1% PSF + deep collection pit	Same distribution for the year 2005	Same distribution for the year 2005	Same distribution for the year 2005	Same distribution for the year 2005
Storage							
swine	61% lagoons;36% tanks;3% covered storage:	54% lagoons; 43% tanks; 3% covered storage:	46% lagoons; 51% tanks; 3% covered storage:	10% lagoons; 79% tanks; 11% covered storage:	7% lagoons; 67% tanks; 25% covered storage:	7% lagoons; 67% tanks; 25% covered storage:	6-7% lagoons; 58-66% tanks; 35-27% covered storage (for sows and other swine, respectively):

Livestock category	1990	2003	2005	2010	2013	2016	2020
covered tanks high reduction: reduction of 80% compared to tanks				1%	3%	3%	10-6%
covered tanks medium reduction: reduction of 60% compared to tanks		1%	1%	4%	5%	5%	16-10%
covered tanks low reduction: reduction of 40% compared to tanks	3%	2%	2%	2.9%	14%	14%	7-9%
Biogas with covered digestate tank: no emission				0.32%(1)	0.80%(1)	1.3%	1.4%
Biogas with open digestate tank				2.7%	2.2%	1.7%	1.6%
Land spreading							
broadcasting	100%	80%	78%	70%	48%	36%	17%
low efficiency		10%	11%	17%	30%	27%	28%
medium efficiency				6%	12%	26%	40%
high efficiency		10%	11%	7%	11%	11%	15%

(1) Data were calculated from the results of the CRPA study on assessing the emission effects of livestock processing (CRPA, 2018). The study estimated that in 2020 3% of swine manure would be sent to anaerobic digestion and 48% of digestate tanks would be covered. Based on these results, it was assumed that: in 2010 and 2013 the percentage of manure sent to digesters remains at 3%, while the percentage of covered digestate tanks changes, becoming 11% and 27% respectively.

Regarding emission factors for swine, the evolution of different abatement technologies throughout the period is considered in the EFs used for NH_3 estimation for housing, storage and land spreading systems. Improvements in the abatement technologies are based on the results of both the IIASA questionnaire for the implementation of RAINS scenarios in 2003 and an ad hoc survey conduct in 2005 by CRPA (CRPA, 2006 [a], [b]). Furthermore, an update of emission factors from livestock housing, manure storage and land spreading for swine category has been estimated based on ISTAT statistics on livestock housing, manure storage systems and land spreading techniques such as 2010 and 2020 Agricultural Census, 2013 and 2016 Farm Structure Survey. A gradual transition to the updated emission factors has been assumed for the intermediate years (for the period 2005-2010, 2010-2013, 2013-2016, 2016-2020) taking into account the gradual penetration of the abatement technologies.

Based on the study for the evaluation of the effects on emissions of livestock management practices carried out by CRPA for the emission scenarios for 2020 and 2030 (CRPA, 2018), NH_3 emissions from storage for swine have been modified considering the average distribution of the covered tanks related to the different ammonia emission reduction efficiencies.

6.2.1.3 Poultry (3B4g)

As regards 3B4gi (laying hens) and 3B4gii (Broilers) categories, NH_3 emissions show different trends. The different trend for laying hens is due to the evolution of different abatement technologies throughout the period, that are considered in the EFs used for NH_3 estimation for housing, storage and land spreading systems. Emission factors used for each of the different abatement technologies for laying hens (as referenced in CRPA, 2006[a]; CRPA, 2006[b]) are reported in Table 6.7.

Table 6.7 AWMS distribution, abatement technologies and EF by manure management system for the laying hens

Emission factors by manure management system	1990	2003	2005	2010	2020
Housing					
open manure storage under cages (for liquid manure) (RS) = 0.220 kg NH_3/head/year (EC, 2003)	100%	20%	11%	4%	14% (of which 11% aviaries without bedding)
deep pit = 0.162 kg NH_3/head/year (ENEA, 2003)		24%			
vertical tiered cages with manure belts and forced air drying = 0.06 kg NH_3/head/year (ENEA 2003) [reduction in ammonia emissions of 73% compared to RS]		56%	74%	50%	31%
vertical tiered cages with manure belt and whisk-forced air drying = 0.088 kg NH_3/head/year (EC, 2003) [reduction in ammonia emissions of 60% compared to RS]			2%		
aerated open manure storage (deep-pit or high-rise systems and canal house) = 0.154 kg NH_3/head/year (EC, 2003) [reduction in ammonia emissions of 30% compared to RS]			10%	11%	4%
vertical tiered cages with manure belt and drying tunnel over the cages = 0.044 kg NH_3/head/year (EC, 2003) [reduction in ammonia emissions of 80% compared to RS]			3%		
Loose housing with outdoor access (RS) = 0.3 kg NH_3/head/year (Bittman S. et al, 2014)				7%	8%
Loose housing without outdoor access = 0.18 kg NH_3/head/year (Bittman S. et al, 2014; our assumptions)				28%	43%
Storage					
liquid manure = 16% (percentage of nitrogen to storage) (Nicholson et al, 2004)	100%	20%	11%	4%	14%
solid manure = 7.3% (ENEA, 2003)		80%	89%	96%	86%
Land spreading					
liquid manure = 37.1% of TAN applied (TAN/TKN = 35%) (CRPA, 2006[a]) [broadcasting]	100%	5%	9%	9%	15%
low efficiency = 7.8% (bandspreading and incorporation within 6 hours for liquid manure) [reduction of 40% compared to broadcasting]		50%	65%	65%	25%
medium efficiency = 5.2% (bandspreading, incorporation within 4 hours, surface injection and open slot, for liquid manure) [reduction of 60% compared to broadcasting]					47%
high efficiency = 2.6% (shallow and deep injection for liquid manure) [reduction of 80% compared to broadcasting]		45%	26%	26%	13%
solid manure = 67% of TAN applied (TAN/TKN = 21%) (Nicholson et al, 2004; CRPA, 2006[a]) [broadcasting]		10%	9%	10%	34%
low efficiency = 11.0% (incorporation within 12-24 hours for solid manure) [reduction of 20% compared to broadcasting]		40%	37%	43%	32%
high efficiency = 2.8% (incorporation within 4 hours for solid manure) [reduction of 80% compared to broadcasting]		50%	54%	46%	33%

Emission factors used for each of the different techniques for housing are derived from ILF BREF of IPPC (EC, 2003) and a study at national level on ammonia emissions from laying hens (ENEA, 2003). Based on the housing distribution collected from the 2010 and 2020 Agricultural Census, the emission factors and abatement systems data reported in the Guidance from the UNECE Task Force on Reactive Nitrogen (Bittman S. et al, 2014), the average emission factors have been updated. For the years 2005-2010 and 2010-2020, a gradual transition to the updated distribution of housing systems has been assumed for the intermediate years taking into account the gradual penetration of systems to ensure animal welfare. From 1995 a chicken-dung drying process system has been introduced for laying hens and improved throughout the period.

As regards manure storage, emission factors are expressed as a percentage of the nitrogen contained in manure to storage. Emission factors used for liquid manure are derived from Nicholson et al (Nicholson et al, 2004) and emission factors for solid manure are from ENEA (ENEA, 2003). Based on the 2010 and 2020 Agricultural Census conducted by ISTAT, an update of emission factors from manure storage for laying hens category has been estimated. A gradual transition to the updated emission factors has been assumed for the intermediate years (for the period 2005-2010 and 2010-2020) considering the gradual penetration of the abatement technologies. EFs for manure storage reported in Table 6.7 have been multiplied by the amount of nitrogen remaining after housing emissions.

For land spreading, emissions have been estimated by CRPA (CRPA, 2006[a]; CRPA, 2006[b]). As regards the liquid manure, the amount of N-NH_4 emissions, in percentage of the applied ammoniacal nitrogen, have been assumed equal to those of the cattle slurry due to the lack of data (CRPA, 2006[a]). As regards the solid manure, the amount of N-NH_4 emissions, in percentage of the applied ammoniacal nitrogen, were equal to 67% (Nicholson et al, 2004; CRPA, 2006[a]). In 2003 and 2005 the evolution of different improvement technologies based on the results of both the IIASA questionnaire for the implementation of RAINS scenarios and a survey conduct by CRPA, has been implemented in the EFs used. For the period 1900-2003, a linear emission reduction has been estimated and applied. The efficiency of reduction techniques has been estimated based on the UNECE document Control techniques for preventing and abating emissions of ammonia (as referenced in CRPA, 2006[a]; CRPA, 2006[b]). Based on the 2010 and 2020 Agricultural Census conducted by ISTAT, an update of emission factors from land spreading for laying hens category has been estimated. EFs for land spreading reported in Table 6.7 have been multiplied by the amount of nitrogen remaining after storage emissions.

Regarding emission factors for broilers, the evolution of different abatement technologies throughout the period is considered in the EFs used for NH_3 estimation for housing, storage and land spreading systems. Improvements in the abatement technologies are based on the results of both the IIASA questionnaire for the implementation of RAINS scenarios in 2003 and an ad hoc survey conduct in the 2005 by CRPA (CRPA, 2006 [a], [b]) and on ISTAT statistics such as 2010 Agricultural Census, 2013 and 2016 Farm Structure Survey.

As recommended by the 2019 and 2020 NECD review (EEA, 2019; EEA, 2020), emissions of NO_x, NH_3, PM and NMVOC from turkeys have been estimated and reported in category 3B4giii.

Regarding equines, the ISTAT statistics used for estimation include equines intended and not intended for food production. From 2018 to 2021, ISTAT did not publish data on stocks, and to 2022, the ISTAT data are those from the National Livestock Registry Database (BDN), which includes all equines bred.

Average emission factors for NH_3 per head are reported in Table 6.8

Table 6.8 NH_3 emission factors for manure management for the year 2023

Category	Housing	Storage	Land spreading	Grazing	Total
			kg NH_3 head-1 yr-1		
Non-dairy cattle	6.53	6.56	4.18	0.97	**18.23**
Dairy cattle	16.66	17.28	10.23	0.75	**44.92**
Buffalo	8.97	9.73	7.74	0.17	**26.61**
Other swine (*)	3.38	1.46	0.83		**5.67**
Sow (*)	5.81	3.09	1.91		**10.81**
Sheep	0.22	0.28	0.32	0.71	**1.53**
Goats	0.22	0.25	0.33	0.71	**1.50**
Horses	3.21	4.43	1.97	2.91	**12.51**
Mules and asses	3.21	4.43	1.97	2.91	**12.51**

Category	Housing	Storage	Land spreading kg NH_3 head-1 yr-1	Grazing	Total
Laying hens	0.14	0.04	0.05		**0.23**
Broilers	0.08	0.04	0.03		**0.14**
Turkeys	0.25	0.15	0.08		**0.48**
Other poultry	0.03	0.01	0.01		**0.04**
Rabbit	0.34	0.13	0.06		**0.54**
Fur animals	1.37		0.30		**1.67**

(*) Other swine and sows are sources that represent the 'swine' category

NH_3 emissions from digesters biogas facilities (in particular due to different phases of the process: during storage of feedstock on the premises of the biogas facility, during the liquid–solid separation of the digestate, during storage of the digestate) have been estimated on the basis of the amount of nitrogen in manure feeding anaerobic digesters and the tier 1 emission factor derived by the EMEP/EEA Guidebook (EMEP/EEA, 2023). Based on CRPA data on measurements of nitrogen quantities in livestock manure (downstream of releases to housing and storage) per animal category and type of manure, the nitrogen quantities in livestock manure sent to anaerobic digestion were estimated. The coefficients, expressed as g N/kg manure, were calculated gross of losses and then the losses to housing were deducted. The resulting coefficients were then multiplied by the quantities of manure sent for anaerobic digestion. The whole time series was updated. NH_3 emissions from digesters biogas facilities have been subtracted from manure management category (for cattle, swine and poultry categories) and allocated in the anaerobic digestion at biogas facilities (5B2 of the waste sector). As requested during the 2019 and 2020 NECD reviews (EEA, 2019; EEA, 2020), the amount of total feedstock, livestock manure and nitrogen in manure treated by biogas facilities are shown in Table 6.9.

Table 6.9 Total feedstock, animal manure and nitrogen in manure treated by biogas facilities.

Year	Total feedstock (t)	Animal manure in total feedstock (t)	Nitrogen in animal manure (kg)
1990	-	-	-
1995	n.a.	273,863	1,173,358
2000	n.a.	165,670	698,951
2005	n.a.	1,078,548	4,399,024
2010	6,513,271	1,766,348	6,971,715
2015	29,551,431	13,600,442	69,171,691
2020	33,114,392	15,217,967	86,287,217
2021	33,845,787	15,529,722	88,228,624
2022	33,464,968	15,343,673	86,194,518
2023	31,997,414	14,674,620	83,950,338

n.a. = not available

Because of multiple substrates fed to bio-digesters, the following average characteristics of the feedstock, reported in Table 6.10, as supplied by CRPA, are considered for the Italian bio-digesters to calculate the total amount of feed from animal manure anaerobic digestion (CRPA, 2018).

Table 6.10 Percentages of different substrates for anaerobic digestion feedstock

Type of feed	Units	animal manure	energy crops	agro-industrial by-products
Animal manure only	% in the feed	100	0	0
Animal manure + energy crops + agro-industrial by-products	% in the feed	28	52	20
Animal manure + energy crops	% in the feed	38	62	0
Animal manure + agro-industrial by-products	% in the feed	69	0	31
Energy crops + agro-industrial by-products	% in the feed	0	81	19

Source: CRPA

Based on the information reported above and in consideration of the typical feed of the bio-digesters the average parameters for animal manure, energy crops and agro-industrial by-products are those reported in Table 6.11. The biogas methane content is generally reported to range from 50% to 65%, for inventory purposes and according to CRPA methane content is assumed to be 55%. As regards the average volatile solids content, values for animal manure and agro-industrial by-products have been changed based on the recent study of CRPA (CRPA, 2018).

Table 6.11 Average parameters of different substrates for anaerobic digestion feedstock

Parameters	Units	animal manure	energy crops	agro-industrial by-products
Average biogas producing potential	m^3 biogas/kg VS	0.4	0.6	0.6
Average CH_4 content	%	55	55	55
Average volatile solids content	kg/t feed	139	280	237

Source: CRPA

For further information on the method of estimating the quantity of manure sent to digesters and the amount of nitrogen stored in digesters, see the information and data reported in the NIR (see paragraphs 5.3.2 Methodological issues in chapter 5 and A7.2 Manure management (3B) in annex 7).

The percentage of nitrogen lost through N-NH_3 emissions from anaerobic digesters was subtracted from the percentage of nitrogen left after emissions during housing and storage, reducing the amount of nitrogen used at the spreading. The amount of nitrogen used at spreading also includes digestate.

For NO_X emissions (during storage) tier 2 method reported in the EMEP/EEA Guidebook (EMEP/EEA, 2023) was used for calculations. EFs by livestock category and manure type derived from the EMEP/EEA Guidebook (EMEP/EEA, 2023) are based on nitrogen mass-flow approach built from country specific data on nitrogen excretion and solid/liquid distribution of manure.

For NMVOC emissions a tier 2 method was used for calculations. Tier 2 NMVOC EFs are those reported in the EMEP/EEA Guidebook (EMEP/EEA, 2023). As requested during the 2020 NECD reviews (EEA, 2020), NMVOC emissions from turkeys are estimated and reported in the 3B4giii category.

In Table 6.12 parameters used to estimate NMVOC emissions of categories 3B1a and 3B1b such as feed intake in MJ, silage fraction, proportion of housing, emission of NH_3 from housing, storage and spreading for 2023 are reported, as requested during the 2023 NECD reviews.

Table 6.12 Parameters of estimate NMVOC emissions of categories 3B1a and 3B1b for 2023

Parameters	Dairy cattle	Non-dairy cattle
GE MJ/capo/year	133,747.66	55,371.55
xhouse %	0.95	0.98
Fracsilage %	0.50	0.40
Fracsilage_store %	0.25	0.25
EF tier 2 silage_feeding kg NMVOC /MJ feed intake	0.0002002	0.0002002
EF tier 2 building kg NMVOC /MJ feed intake	0.0000353	0.0000353
EF tier 2 grazing kg NMVOC /MJ feed intake	0.0000069	0.0000069
ENMVOC, silage_store kg NMVOC/head	3.18	1.08
ENMVOC, silage_feeding kg NMVOC/head	12.72	4.34
ENMVOC, house kg NMVOC/head	4.49	1.91
ENH_3, building tons	21,600.82	21,547.71
ENH_3, storage tons	22,401.37	21,635.11
ENH_3, application tons	13,261.46	13,806.93
ENMVOC, manure_store kg NMVOC/head	4.65	1.92
ENMVOC, MM g NMVOC/head	25,035.10	9,249.84
Head number	1,574,406	4,007,697
ENMVOC, MM kt NMVOC	39.42	37.07

For particulate matter emissions a tier 1 method was used for calculations. EFs for PM10 and PM2.5 are derived from the EMEP/EEA Guidebook (EMEP/EEA, 2023; EMEP/CORINAIR, 2006), modified based on the Italian animal breeding characteristics and weight parameters. For swine and poultry, up to 2004 the emission factors from the 2006 EMEP/CORINAIR Guidebook were used and from 2010 PM emission estimates are based on emission factors provided by the 2023 EMEP/EEA Guidebook. From 2005 to 2009 a gradual shift in emission factors was estimated, reflecting a gradual change in manure management systems, based on the studies underlying the emission factors in the two versions of the Guidebook and on data recorded by ISTAT surveys (FSS and the agricultural census). The 2023 EMEP/EEA emission factors are based on studies conducted between 2006 and 2016 which include scientific works conducted in Italy. These studies have suggested that Takai's emission factors suggested in the 2006 EMEP/CORINAIR Guidebook are too high and do not represent current particulate emission levels.

PM emissions from turkeys are estimated and reported in the 3B4giii category.

PM emissions from turkeys, sheep, goats, mules and asses and fur animals are also estimated. PM emission factors for sheep, goats, mules and asses and fur animals are from EMEP/EEA Guidebook 2023, Table A1.7 EFs for inhalable dust, respirable dust, PM10 and PM2.5. For turkeys were used the factors in Table 3.5 Default Tier 1 estimates of EF for particle emissions from livestock husbandry (housing). The emission factors reported in Table 6.13 are the result of the product of the Guidebook emission factors and the ratio between the Guidebook average weights (reported in Table A1.5 Conventional livestock units and weights of livestock on which the N excretion estimates in Table 3.9 were based) and those of the national inventory by animal category. Average emission factors for PM per head are reported in Table 6.13.

Table 6.13 PM emission factors for manure management for the year 2023

Category	PM10	PM2.5
	kg PM head-1 yr-1	
Non-dairy cattle	0.323	0.213
Dairy cattle	0.691	0.449
Buffalo	0.498	0.326
Other swine (*)	0.187	0.008
Sow (*)	0.233	0.012
Sheep	0.054	0.016
Goats	0.055	0.017
Horses	0.242	0.154
Mules and asses	0.137	0.086
Laying hens	0.033	0.002
Broilers	0.024	0.002
Turkeys	0.109	0.020
Other poultry	0.021	0.003
Rabbit	-	-
Fur animals	0.003	0.002

(*) Other swine and sows are sources that represent the 'swine' category

6.3 AGRICULTURAL SOILS (3D)

For agricultural soils, estimations of NH_3 emissions account for the direct application of synthetic N-fertilizers (3Da1), animal manure applied to soils (3Da2a), sewage sludge applied to soils (3Da2b), other organic fertilisers applied to soil (3Da2c), animal grazing (3Da3), crop residues applied to soils (3Da4) and N fixed by leguminous crops (3De). For the same sources, emissions of NO_X were estimated (except for 3De cultivated crops and 3Da4 crop residues applied to soils). Indirect emissions from managed soils (3Db) and off-farm storage, handling and transport of bulk agricultural products (3Dd) have not been estimated as in the guidelines there is insufficient information. PM10 and PM2.5 emissions from the Farm-level agricultural operations including storage, handling and transport of agricultural products have been estimated and reported in 3Dc category. NMVOC emissions from animal manure applied to soils, animal grazing and cultivated crops have been estimated and reported in 3Da2a, 3Da3 and 3De categories respectively. HCB emissions from the use of pesticides have been estimated and reported in 3Df category.

NH_3 emissions from synthetic N-fertilizer (3Da1) are based on the guidebook methodology (EMEP/EEA, 2023), which provides different EFs by type of fertilizers and pH of the soil (EFs in Table 6.2). A tier 2 method has been implemented for 3Da1 source. NH_3 emissions from synthetic N-fertilizers are obtained with the amount of the N content by type of fertilizer multiplied by the specific EFs. NH_3 EFs from the use of synthetic fertilizers for normal and high pH factors (reported in the EMEP/EEA Guidebook (EMEP/EEA, 2023)) have been updated. To calculate a weighted average of emission factors distinguished according to soil pH type, CREA-AA[3] processed the national agricultural areas distinguished according to eight soil pH classes, finally calculating the area percentages for normal and high pH (Rivieccio R., 2019).

[3] Council for Agricultural Research and Analysis of Agricultural Economics - Agriculture and Environment

Based on the comparison with ASSOFERTILIZZANTI and ISTAT experts on the time series of synthetic fertiliser use, the nitrate data in the years 2009-2011 were revised for the current submission. In addition, nitrate data (quantity and nitrogen content) were recalculated to include the estimated CAN fertiliser. The emission factor of NH_3 for the use of CAN from the EMEP/EEA Guidebook (EMEP/EEA, 2023) has been used. NO_X emission factor for synthetic N-fertilizer is equal to 0.04 kg NO_2/kg fertiliser N applied (EMEP/CORINAIR, 2023).

The method for estimating NH_3 emissions from animal manure applied to soils (3Da2a) is described in 3B (tier 2). Based on ISTAT statistics on spreading systems such as 2010 and 2020 Agricultural Census, 2013 and 2016 Farm Structure Survey, an update of emission factors from land spreading for cattle, swine, laying hens and broilers categories have been estimated. A gradual transition to the updated emission factors has been assumed for the intermediate years (for the period 2005-2010, 2010-2013, 2013-2016 and 2016-2020) taking into account the gradual penetration of the abatement technologies. For NO_X emissions (during spreading) a tier 2 method was used for calculations. EFs by livestock category and manure type derived from the EMEP/EEA Guidebook (EMEP/EEA, 2023) are based on nitrogen mass-flow approach. For NMVOC emissions a tier 2 method was used for calculations. Tier 2 NMVOC EFs are those reported in the EMEP/EEA Guidebook (EMEP/EEA, 2023).

Concerning the sludge spreading (3Da2b), the total production of sludge from urban wastewater plants, as well as the total amount of sludge used in agriculture and some parameters such as N content, are communicated from 1995 by the Ministry for the Environment, Land and Sea from 1995 (MATTM, several years[a]) in the framework of the reporting commitments fixed by the European Sewage Sludge Directive (EC, 1986) transposed into the national Legislative Decree 27 January 1992, n. 99. From 1990 to 1994 activity data and parameters were reconstructed, as reported in detail in the Chapter 7 of the National Inventory Report/Document on the Italian greenhouse gas inventory (ISPRA, several years [a]).

The amount of sewage N applied was calculated using the amount of sewage sludge (expressed in tons of dry matter) and the N content of sludge. The dry matter contained in sludge at national level is assumed to be 25% of total sludge. In Table 6.14, the total amount of sewage sludge production as well as sludge used in agriculture and nitrogen content in sludge is reported. The default NH_3 EF (0.13 kg NH_3/kg N applied) and NO_x EF (0.04 kg NO_2/kg N applied) are from EMEP/EEA Guidebook (EMEP/EEA, 2023).

Table 6.14 Sludge spreading activity data and parameters, 1990 – 2023.

Year	Sewage sludge production (t)	Sewage sludge used in agriculture (t)	Sewage sludge used in agriculture (t of dry matter)	N concentration in sludge (% dry matter)	Total N in sludge (t)
1990	3,272,148	392,658	98,164	5	5,071
1995	2,437,024	630,046	157,512	5	8,137
2000	3,402,017	869,696	217,424	5	10,954
2005	4,298,576	862,970	215,742	4	8,874
2010	3,697,625	992,859	248,215	4	10,040
2015	3,069,302	888,899	222,225	4	8,303
2020	3,390,368	721,659	180,415	4	7,078
2021	3,238,141	686,838	171,710	4	6,745
2022	2,936,372	716,735	179,184	4	6,950
2023	2,942,750	717,969	179,492	4	7,180

As regards the other organic fertilisers applied to soil (3Da2c) category, the use of other organic N fertilisers, including compost and organic amendments, and N content are provided by ISTAT (as reported in paragraph 6.1). The default NH_3 EF (0.08 kg NH_3/kg waste N applied) and NO_x EF (0.04 kg NO_2/kg N waste applied) are from EMEP/EEA Guidebook (EMEP/EEA, 2023). For 3Da3 the time series of the quantity of N from animal grazing is the same as that reported in the NIR and in the relevant CRF tables. The method for estimating NH_3 emissions is described in 3B (tier 2). The default NO_X EF is from EMEP/EEA Guidebook (EMEP/EEA, 2023). For NMVOC emissions a tier 2 method was used for calculations. Tier 2 NMVOC EFs are those reported in the EMEP/EEA Guidebook (EMEP/EEA, 2023).

Nitrogen input from N-fixing crops (3De) has been estimated starting from data on surface and production for N-fixing crops and forage legumes; nitrogen input from N-fixing crops (kg N yr-1) is calculated with a country-specific methodology. Peculiarities that are present in Italy were considered: N-fixing crops and legumes forage. Nitrogen input is calculated with two parameters: cultivated surface and nitrogen fixed per hectare (Erdamn 1959 in Giardini, 1983). Emissions are calculated using the default emission factor 1 kg N-NH_3/ha (EMEP/CORINAIR, 2006). In Table 6.15, cultivated surface from N-fixing species (ha yr-1) and N fixed by each species (kg N ha-1 yr-1) are shown.

Table 6.15 Cultivated surface (ha) and nitrogen fixed by each variety (kg N ha-1 yr-1)

N fixed		1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
kg N $ha^{-1}yr^{-1}$						ha					
Bean, f,s.	40	29,096	23,943	23,448	23,146	19,027	17,059	17,915	18,378	15,748	16,708
Bean, d.s.	40	23,002	14,462	11,046	8,755	7,001	5,870	5,541	5,265	3,489	4,326
Broad bean, f.s.	40	16,564	14,180	11,998	9,484	8,487	7,914	7,372	7,310	7,212	7,022
Broad bean, d.s.	40	104,045	63,257	47,841	48,507	52,108	42,157	61,982	57,207	50,058	45,437
Pea, f,s.	50	28,192	21,582	11,403	11,636	8,691	14,940	16,154	15,730	16,428	15,166
Pea, d.s.	72	10,127	6,625	4,498	11,134	11,692	11,181	20,766	17,771	16,033	15,046
Chickpea	40	4,624	3,023	3,996	5,256	6,813	11,167	18,579	17,617	14,068	14,227
Lentil	40	1,048	1,038	1,016	1,786	2,458	3,099	5,612	5,710	4,925	5,253
Vetch	80	5,768	6,532	6,800	7,142	7,560	7,795	7,827	7,827	7,827	7,827
Lupin	40	3,303	3,070	3,300	2,500	3,401	3,358	570	650	710	710
Soya bean	58	521,169	195,191	256,647	152,331	159,511	308,979	256,134	285,464	342,532	310,721
Alfalfa	194	987,000	823,834	810,866	779,430	745,128	667,325	715,642	694,481	684,187	676,361
Clover grass	103	224,087	125,009	114,844	103,677	102,691	119,942	127,270	124,308	143,941	165,566
Total		**1,958,025**	**1,301,746**	**1,307,702**	**1,164,784**	**1,134,567**	**1,220,786**	**1,261,364**	**1,257,717**	**1,307,158**	**1,284,371**

NMVOC emissions from cultivated crops have been estimated and reported in 3De category. The method (tier 1) for estimating NMVOC emissions from cultivated crops (3De) is described in 3D chapter of the EMEP/EEA Guidebook (EMEP/EEA, 2023). The default NMVOC EF is from EMEP/EEA Guidebook (EMEP/EEA, 2023). Hectares of wheat, rape, rye crops surface and total grass surface were considered as activity data according to the methodology EMEP/EEA Guidebook (EMEP/EEA, 2023).

NH_3 emissions from crop residues applied to soils have been estimated and reported in 3Da4 category. The method (tier 2) for estimating NH_3 emissions from crop residues (3Da4) is described in 3D chapter of the EMEP/EEA Guidebook (EMEP/EEA, 2023). Agricultural areas (cereals, legumes, tubers, vegetables, industrial crops, temporary and permanent fodder crops), above-ground residues, nitrogen content, and removed, burned and incorporated fractions of residues are country-specific data already used in estimating N_2O emissions from crop residues returned to soils. Regarding the incorporated fraction, incorporation is assumed to occur after 3 days, except in areas where green manure practice occurs. Green manure practice involves chopping cover crops and then incorporating them into the soil. The two operations are accomplished within 3 days. Therefore, according to the 2023 EMEP/EEA Guidebook, there is no NH_3 emission for these residues. CREA-AA provided data on green manure areas by crop for the years 2019-2022, extracted from the FADN database (CREA, 2024).

PM10 and PM2.5 emissions from the Farm-level agricultural operations including storage, handling and transport of agricultural products have been estimated and reported in 3Dc category. The method (tier 1) for estimating PM10 and PM2.5 emissions is described in 3D chapter of the EMEP/EEA Guidebook (EMEP/EEA, 2023). The default PM10 and PM2.5 EFs are from EMEP/EEA Guidebook (EMEP/EEA, 2023). Hectares of total arable crop surface have been used as activity data for PM emissions according to the methodology EMEP/EEA Guidebook (EMEP/EEA, 2023).

HCB emissions from the use of pesticides (3Df) have been estimated. HCB emissions result from the use of HCB as pesticide but also using other pesticides which contain HCB as an impurity. For the period 1996-2001, data are from the database of pesticides contained in the National agricultural information system (*Sistema informativo agricolo nazionale* - SIAN[4]). For the period 2002-2008, SIAN data have been elaborated by Provincial Agency for the Protection of the Environment of the Autonomous Province of Trento[5]. From 2009 activity data have been processed by the Service for risks and environmental sustainability of technologies, chemical substances, production cycles and water services and for inspection activities of ISPRA based on data provided by ISTAT related to substances chlorothalonil, picloram, lindane and chlortal-dimetile which are the active ingredients of pesticides containing HCB.

The availability of data allows estimating emissions from pesticides where HCB is found as an impurity, as in lindane, DCPA, chlorothalonil and Picloram. Emissions from the use of HCB as a pesticide were not estimated. As result of the 2020 NEC review, the HCB emissions from the use of pesticides have been revised. On the basis of the amount of HCB contained in these pesticides (lindane: 0.005%; DCPA: 0.004%; chlorothalonil: 0.004%; Picloram: 0.005%) and according to the EMEP/EEA Guidebook (EMEP/EEA, 2023), which states all the HCB present as a contaminant will be volatilised, HCB emissions result in 118.82 kg for 1990 and 0.00284 kg in 2020. An international research work at European level (Berdowski et al., 1997) estimated 400 kg of HCB emissions from pesticide use for Italy in 1990 while in the last years these emissions should be null. From 2021, emissions are zero as there are no more substances sold that contain HCB, according to ISTAT data.

Detailed information on activity data sources, methods and EFs by pollutant for 3D category is shown in Table 6.16.

[4] http://www.sian.it/portale-sian/attivaservizio.jsp?sid=174&pid=6&servizio=Banca+Dati+Fitofarmaci&bottoni=no

[5] http://www.appa.provincia.tn.it/fitofarmaci/programmazione_dei_controlli_ambientali/-Criteri_vendita_prodotti_fitosanitari/pagina55.html

Table 6.16 Activity data sources, methods and emission factors by pollutant for agriculture soils

NFR code	Category	Method	Activity data	Emission factor
3Da1	Inorganic N-fertilizers (includes also urea application)	T2 (NH_3), T1 (NO_X)	NS	T2 (NH_3), D (NO_X)
3Da2a	Animal manure applied to soils	T2 (NH_3, NO_X, NMVOC)	NS	CS (NH_3), D (NO_X), T2 (NMVOC)
3Da2b	Sewage sludge applied to soils	T1 (NH_3, NO_X)	NS	D (NH_3, NO_X)
3Da2c	Other organic fertilisers applied to soils (including compost)	T1 (NH_3, NO_X)	NS	D (NH_3, NO_X)
3Da3	Urine and dung deposited by grazing animals	T2 (NH_3, NO_X, NMVOC)	NS	CS (NH_3), D (NO_X), T2 (NMVOC)
3Da4	Crop residues applied to soils	T2 (NH_3)	NS	T2 (NH_3)
3Db	Indirect emissions from managed soils			
3Dc	Farm-level agricultural operations including storage, handling and transport of agricultural products	T1 (PM10, PM2.5)	NS	D (PM10, PM2.5)
3Dd	Off-farm storage, handling and transport of bulk agricultural products			
3De	Cultivated crops	CS (NH_3), T1 (NMVOC)	NS	D (NH_3, NMVOC)
3Df	Use of pesticides	T1 (HCB)	NS	D (HCB)

6.4 FIELD BURNING OF AGRICULTURAL RESIDUES (3F)

NMVOC, CO, NO_X, NH_3, SO_2, PM10, PM2.5, BC, As, Cr, Cu, Ni, Se, Zn, Pb, Cd, Hg, Dioxin and PAH emissions have been estimated, applying the tier 1 and tier 2 approach (for heavy metals, PAH emissions and BC). A detailed description of the methodology and parameters used is shown in the NIR (ISPRA, several years [a]). The same methodology to estimate emissions from open burning of waste, as reported in paragraph 7.2 of the waste section (see Small scale waste burning (5C2) subparagraph), is used on the basis of the amount of fixed residues instead of removable residues.

Concerning NO_X and CO, IPCC emission factors have been used (IPCC, 2006), while for PM10, PM2.5, NMVOC, BC, NH_3, SO_2, heavy metals, dioxin and PAH emission factors from the EMEP/EEA Guidebook (EMEP/EEA, 2023) have been applied.

6.5 TIME SERIES AND KEY CATEGORIES

The following sections present an outline of the main key categories in the agriculture sector.

The agriculture sector is the main source of NH_3 emissions in Italy; for the main pollutants, in 2023 the sector accounts for:

- 91.4% of national total NH_3 emissions
- 14.1% of national total NMVOC emissions
- 10.7% of national total PM10 emissions
- 8.9% of national total NO_X emissions
- 3.2% of national total Cd emissions
- 2.8% of national total PM2.5 emissions

Moreover, the sector comprises 0.5% of BC emissions, 0.8% of CO, 0.7% of PAH, 0.4% of Hg, 0.1% of Se, 0.1% of SO_2, 0.04% of Cr, 0.03% of As, 0.03% of Dioxins, 0.03% of Ni, 0.01% of Zn, 0.01% of Pb and 0.003% of Cu. There are no particular differences as compared to the sectoral share in 1990 when the agriculture sector accounted for 94.4% of NH_3 emissions, 9.4% of PM10, 2.6% of PM2.5, except for NMVOC emissions (7.7%), NO_X emissions (2.9%) and HCB emissions where agriculture accounted for 83.4% of total national emissions.

Table 6.17 reports the key categories identified in the agriculture sector while the time series of NH_3 emissions by sources is shown in Table 6.18.

Concerning NH_3 emissions, the category manure management (3B) represents in 2023 49.7% of national total ammonia emissions (51.3% in 1990). NH_3 emissions from cattle (3B1) stand for 55.7% of 3B emissions, while emissions from swine (3B3) and poultry (3B4g) represent 20.5% and 12.5%, respectively. The category agricultural soils (3D) represents in 2023 41.6% of national total ammonia emissions (43.0% in 1990). The use of synthetic N-fertilisers (3Da1) and animal manure applied to soils (3Da2a) represent 50.2% and 33.2% of 3D emissions, respectively.

Regarding PM10 emissions, the category manure management (3B) accounts for 5.0% in 2023 (5.4% in 1990) of national total PM10 emissions. Poultry (3B4g), cattle (3B1) and swine (3B3) represent the major contributors to the total PM10 emissions from category 3B with 54.0%, 24.2% and 14.5%, respectively. The category Farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc) accounts for 5.3% in 2023 (3.7% in 1990) of national total PM10 emissions. For PM2.5 emissions, the category manure management (3B) accounts for 1.8% in 2023 (1.9% in 1990) of national total PM2.5 emissions. Cattle (3B1) accounts for 61.3%, while poultry (3B4g) stands for 23.7% to the total PM2.5 emissions from category 3B. The category Farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc) accounts for 0.3% in 2023 (0.2% in 1990) of national total PM2.5 emissions.

Concerning NO_X emissions, the category manure management (3B) represents in 2023 0.25% of national total NO_X emissions (0.10% in 1990). For NO_X emissions, the category agricultural soils (3D) accounts for 8.6% in 2023 (2.8% in 1990) of national total NO_X emissions. Inorganic N-fertilizers (3Da1) and Animal manure applied to soils (3Da2a) account for 41.2% and 34.6% of total 3D emissions, respectively.

Concerning NMVOC emissions, the category manure management (3B) represents in 2023 11.6% of national total NMVOC emissions (6.1% in 1990). For NMVOC emissions, the category agricultural soils (3D) accounts for 2.4% in 2023 (1.4% in 1990) of national total NMVOC emissions. For NMVOC emissions, the category manure management (3B) and agricultural soils (3D) accounts for 82.4% and 17.3% in 2023 of agricultural NMVOC emissions. Cattle (3B1), poultry (3B4g) and buffalo (3B4a) represent the major contributors to the total NMVOC emissions from category 3B with 75.7%, 13.4% and 5.1%, respectively. Most of the emissions in the 3D category (66.4%) derive from Animal manure applied to soils (3Da2a).

Table 6.17 Key categories in the agriculture sector in 2023.

	SO_x	NO_x	NH_3	NMVOC	CO	PM10	PM2.5	BC	Pb	Cd	Hg	PAH	DIOX	HCB	PCB
							%								
3B1a		0.05	13.98	4.53		0.55	0.51								
3B1b		0.07	13.72	4.26		0.65	0.61								
3B2		0.02	0.84	0.09		0.18	0.08								
3B3		0.00	10.18	0.32		0.72	0.04								
3B4a		0.01	2.04	0.59		0.11	0.10								
3B4d		0.00	0.12	0.01		0.03	0.01								
3B4e		0.01	0.73	0.11		0.04	0.04								
3B4f		0.00	0.15	0.01		0.01	0.00								
3B4gi		0.02	1.96	0.26		0.69	0.07								

	SO_x	NO_x	NH_3	NMVOC	CO	PM10	PM2.5 %	BC	Pb	Cd	Hg	PAH	DIOX	HCB	PCB
3B4gii		0.03	3.12	0.57		1.24	0.18								
3B4giii		0.01	0.99	0.26		0.55	0.14								
3B4giv		0.00	0.16	0.46		0.21	0.04								
3B4h		0.02	1.71	0.13		0.00	0.00								
3Da1		3.54	20.87												
3Da2a		2.98	13.81	1.62											
3Da2b		0.05	0.24												
3Da2c		0.77	2.24												
3Da3		1.26	3.06	0.02											
3Da4			0.94												
3Dc						5.30	0.29								
3De			0.41	0.80											
3Df															
3F	0.09	0.07	0.10	0.04	0.77	0.47	0.63	0.55	0.01	3.20	0.42	0.70	0.03		

Note: key categories are shaded in blue

Table 6.18 Time series of ammonia emissions in agriculture (Gg)

NFR SECTOR 3	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
3B1a Manure management - Dairy cattle	93.01	75.41	70.71	62.43	59.79	58.90	54.35	53.79	54.73	53.43
3B1b Manure management - Non-dairy cattle	88.58	86.82	84.74	74.22	68.03	58.15	58.65	57.17	52.79	52.44
3B2 Manure management - Sheep	4.34	5.30	5.51	3.95	3.92	3.55	3.49	3.34	3.26	3.23
3B3 Manure management - Swine	36.65	35.01	35.56	37.05	40.12	37.88	36.95	36.33	37.11	38.90
3B4a Manure management - Buffalo	3.06	4.54	5.80	6.41	10.33	7.82	7.80	7.78	7.84	7.79
3B4d Manure management - Goats	0.58	0.63	0.63	0.44	0.45	0.44	0.49	0.49	0.47	0.45
3B4e Manure management - Horses	2.20	2.40	2.14	2.13	2.85	2.94	2.81	2.81	2.79	2.79
3B4f Manure management - Mules and asses	0.64	0.29	0.25	0.23	0.35	0.54	0.55	0.55	0.58	0.58
3B4gi Manure management - Laying hens	13.87	12.68	9.56	6.30	7.84	7.14	7.73	7.49	7.41	7.49
3B4gii Manure management - Broilers	12.37	12.96	12.17	11.77	12.00	12.50	11.92	11.97	11.67	11.91
3B4giii Manure management - Turkeys	7.30	7.24	7.18	5.42	6.08	5.80	4.36	4.15	3.05	3.79
3B4giv Manure management - Other poultry	1.76	4.06	3.15	4.62	2.35	1.18	0.73	0.70	0.53	0.62

NFR SECTOR 3	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
3B4h Manure management - Other animals (*)	7.51	8.41	8.79	10.00	8.69	7.72	5.29	5.22	6.04	6.52
3Da1 Inorganic N-fertilizers (includes also urea application)	112.92	114.72	113.17	110.54	74.69	78.45	89.31	82.41	43.94	79.78
3Da2a Animal manure applied to soils	95.13	86.86	78.99	70.07	66.31	62.68	54.02	53.46	52.54	52.79
3Da2b Sewage sludge applied to soils	0.66	1.06	1.42	1.15	1.31	1.08	0.92	0.88	0.90	0.93
3Da2c Other organic fertilisers applied to soils (including compost)	1.32	1.45	1.81	1.78	3.29	6.68	9.82	8.81	12.16	8.57
3Da3 Urine and dung deposited by grazing animals	10.09	11.33	11.48	8.74	9.99	10.89	12.52	12.23	11.81	11.71
3Da4 Crop residues applied to soils	5.07	5.17	4.75	4.56	3.89	3.29	3.75	3.37	3.09	3.58
3De Cultivated crops	2.38	1.58	1.59	1.41	1.38	1.48	1.53	1.53	1.59	1.56
3F Field burning of agricultural residues	0.48	0.47	0.47	0.55	0.41	0.40	0.37	0.38	0.36	0.37
Total	**499.89**	**478.41**	**459.87**	**423.78**	**384.09**	**369.51**	**367.33**	**354.85**	**314.66**	**349.23**

Note: (*) 3B4h includes rabbits and fur animals

The largest and most intensive agricultural area in Italy is the Po River catchment with the following characteristics: high crop yields due to climatic factors, double cropping system adopted by livestock farms, flooded rice fields, high livestock density and animal production that keep animals in stables all the year (Bassanino et al 2011, Bechini and Castoldi 2009). 64%, 78% and 88% of cattle, poultry and swine production are located in Piedmont, Lombardy, Emilia-Romagna, and Veneto Regions (Northern Italy/Po River Basin). At regional level, the presence of large cattle, poultry and swine farms in the Po basin assume a particular relevance for air quality issues, especially, for the specific meteorological conditions of this area.

In Figure 6.2 NH_3 emissions from main categories of 3B are reported.

Figure 6.2 NH_3 emissions from 3B cattle, swine and poultry categories.

The reduction of NH_3 emissions from 3B is mainly related to the reduction in the number of animals. Between 1990 and 2023 total NH_3 emissions from 3B have reduced by 30.1%. Cattle livestock decreased by 28.0% (from 7,752,152 to 5,582,103 heads). Dairy cattle and non-dairy cattle have decreased by 40.4% and 21.6%, respectively. The so-called first pillar of the EU Common Agriculture Policy (CAP), dealing with market support, had a strong impact through the milk quota system by reducing animal numbers in the dairy sector to compensate for increasing animal productivity (EEA, 2016).

Swine have increased between 1990 and 2023 by 9.1% while poultry have increased much less (see Table 6.1).

Regarding the number of swine, the increase in 2001 and in the following years was due to an increase in demand for pork meat favored by more competitive prices compared to other meats, but also to the diseases affecting beef (Bovine Spongiform Encephalopathy - BSE) and poultry (bird flu). The reduction in the number of swine in 2012, which affected all sub-categories (piglets, fattening pigs and breeding pigs), was affected by the implementation of Directive 2008/120, which set new standards in terms of the welfare of pigs and in particular sows in breeding wards.

Abatement technologies are considered in the EFs used for NH_3 estimations. Research studies funded by ISPRA, such as the MeditAiraneo project, or by the Ministry of Environment, and ISTAT statistics, such as Agricultural Census and Farm Structure Survey, have allowed us to collect information on the inclusion of abatement technologies in Italy, especially those related to the cattle, swine and poultry housing, treatment of manure and to land spreading.

Emission abatement techniques change the emission factors (which are a weighted average of the emission factors between the reference, unabated system, and systems that emit less). The change in emission factors combined with the change in the number of animals changes the emission trend.

NH_3 emissions of 3D category are driven by the use of inorganic N-fertilizers, that are decreased overall by 35.0% (in particular urea decreased by 8.9%), in terms of nitrogen content, and the animal manure applied to soils. Between 1990-2023 emissions have respectively decreased by 29.3% and 44.5% mainly due to the reduction of the use of inorganic N-fertilizers and of number of livestock raised and the application of emission reduction techniques.

The interannual variability of ammonia emissions from synthetic fertilisers depends entirely on the data provided by ISTAT on the distributed quantities of synthetic fertilisers and on the quantities of nitrogen they contain. While the emission factors are constant throughout the time series. For the years 2012 and 2016, the increase in distributed urea almost completely explains the overall increase in emissions from synthetic fertilisers. In 2020, 70% of the increase is explained by the increase in urea and 30% by the increase in other synthetic fertilisers.

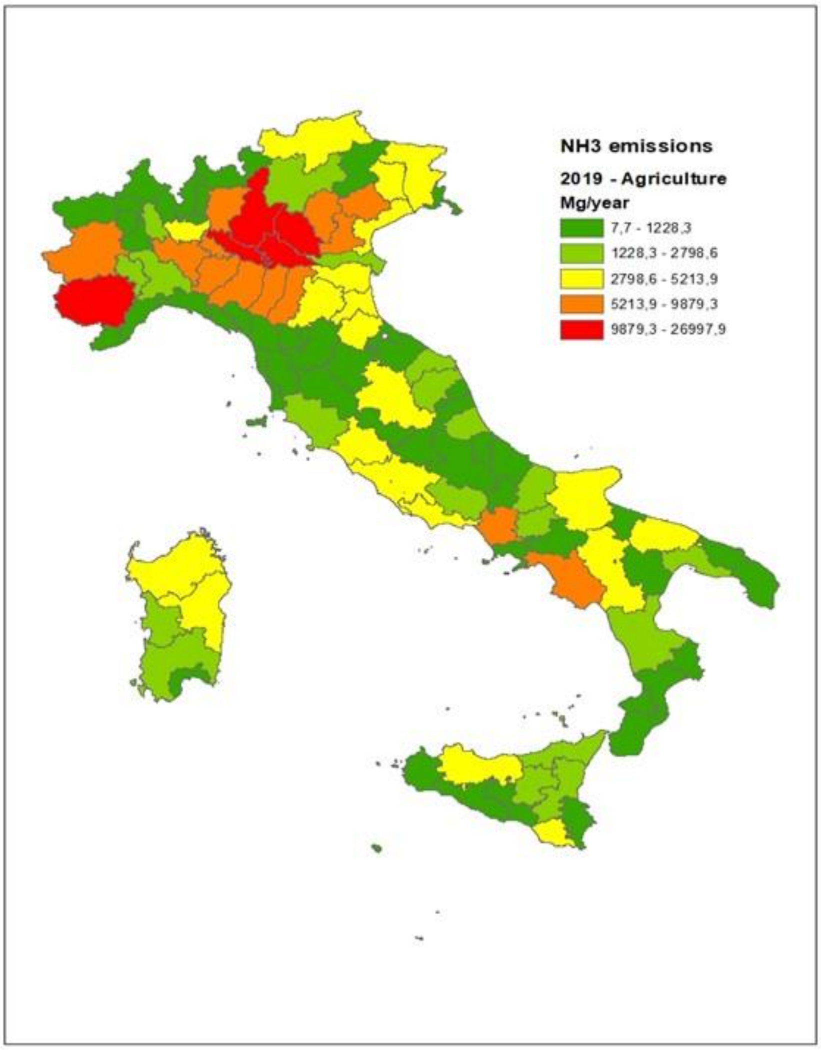
According to Assofertilizzanti–Federchimica[6], in relation to the 2020-2022 data, farmers tend to anticipate purchases (and thus stockpile) when expectations of rising market prices are present. The 2022 data are lower than annual average (for nitrogen, phosphorus pentoxide, and potassium oxide) because they follow a two-year period in which quantities purchased increased and refer to a year in which high market prices prompted operators to delay purchases in anticipation of falling prices, an event, which actually occurred during 2023.

Furthermore, the EU Nitrates Directive which aims at reducing and preventing water pollution caused by nitrates from agricultural sources has addressed the lower use of synthetic and nitrogen-based fertilisers (EEA, 2016).

Every 4 years the national emission inventory is disaggregated at NUTS3 level as requested by CLRTAP. A database with the time series for all sectors and pollutants has been published (ISPRA, 2022; ISPRA, 2021; ISPRA, 2009; ISPRA, several years[c]; ISPRA, several years[d]). The disaggregation of 2019 agricultural emissions has also been finalized and figures are available at the following web site: https://emissioni.sina.isprambiente.it/inventari-locali/ The disaggregation (NUTS3) of the NH_3 agricultural emissions is shown in Figure 6.3. In 2019, four regions contributed more than 60% of agricultural NH_3 emissions: Lombardia, Veneto, Emilia Romagna and Piemonte.

[6] Federchimica is the National Association of the Chemical Industry and Assofertilizzanti represents the production companies of the fertilizer industry.

Figure 6.3 NH_3 emissions from Agriculture in 2019 (t)



6.6 QA/QC AND VERIFICATION

QA/QC procedures for the agriculture sector are in line with the 2006 IPCC Guidelines and consistent with the EMEP/EEA Guidebook. Italy has drawn up a QA/QC procedure manual and elaborates annually a QA/QC plan both for the UNFCCC and UNECE/CLRTAP inventories. In the QA/QC Agriculture section GHG and NH_3 emissions improvements are specified (ISPRA, several years [b]). Furthermore, feedback for the agricultural emission inventory derives also from communication of data to different institutions (ISTAT, UNAITALIA, CRPA etc.) and/or at local level (regional environmental institutions). In addition, ISPRA participates in a technical working group on agriculture within the National Statistical System, composed of producers and users of agricultural statistics.

In 2011 a validation of EFs and estimations was carried out considering the results of a research study that estimated at NUTS 2 level emissions for the use of synthetic N-fertilizers considering type of cultivation, altitude, and climatic conditions (CRPA, 2010[b]).

Data used to estimate emissions were verified with census data. Differences in the livestock number are found comparing conjunctural surveys (used for emissions estimation) and the Agricultural census for the year 2020: +5% non-dairy cattle, +3% poultry, -2% buffalo and swine, +12% goats, while equines are almost three times as large.

Data on national sales of synthetic nitrogen fertilizers (by type of fertilizers) as provided by Assofertilizzanti (data are available online - https://assofertilizzanti.federchimica.it/fertilizzanti/statistiche-fertilizzanti) for the period 2011-2023 have been compared to official statistics provided by ISTAT. ISTAT simple mineral nitrogen fertilizers data are about 11% lower than those of Assofertilizzanti, for the years 2011-2023. These differences in recent years could be attributable to rising fertilizer prices. ISTAT statistics almost certainly do not consider that farmers tend to anticipate purchases (and thus stockpile) when expectations of rising market prices are present. The 2022 data are lower than annual average (for nitrogen, phosphorus pentoxide, and potassium oxide) because they follow a two-year period in which quantities purchased increased and refer to a year in which high market prices prompted operators to delay purchases in anticipation of falling prices, an event, which occurred during 2023 (as per ISTAT data).

Ammonia emissions for swine and poultry manure management from housing and storage were compared with data reported in the E-PRTR registry for the year 2019 for swine and poultry, which represent 36.8% of national NH_3 emissions for the same categories (3B).

In 2021, a technical report (CREA, 2021) produced by CREA, in collaboration with ISPRA, on the assessment of emissions related to the use of nitrogen fertilizers was published, which contains several analyses of nitrogen fertilizer consumption data from different data sources: IFASTAT/Fertilizer Europe, FAO, EUROSTAT, Assofertilizzanti, National Integrated Production Specifications, Farm Accountancy Data Network (FADN). These analyses suggest further investigation to better understand the differences found between these data sources and the ISTAT data used for the estimates.

In 2021, NH_3 emissions for dairy cows were also calculated with the AgrEE tool - Agricultural Emission Estimation tool (made by the JRC) and differences with national estimates for the year 2015 were analysed. National estimates are slightly higher than the AgrEE tool results (16.5 kt N-NH_3 for spreading vs 16.1 kt N-NH_3) for several reasons. In particular two of them are: for N_2O emissions from storage, according to the Guidebook, it is necessary to remove emissions from housing, while IPCC considers the N excreted at the housing; for NH_3 emissions from spreading, the Guidebook does not remove N lost through leaching and run-off at storage, unlike the IPCC methodology. The verification with AgrEE tool revealed other differences that will be taken into account for improved emission estimates.

6.7 RECALCULATIONS

In 2025, recalculations were implemented for the agricultural emission inventory.

Changes related to NH_3 emissions are described below.

The percentages of dairy cattle and non-dairy cattle on pasture have been changed since 2007, based on data from the 2020 Agriculture Census (whose data were made available by ISTAT in 2024).
An update of EF NH_3 from livestock housing of dairy cattle, non-dairy cattle, buffaloes, and laying hens since 2011 and swine since 2006 was carried out, based on the Census Agriculture 2020.
An update of EF NH_3 from storage of dairy cattle and non-dairy cattle from 2013 and sows and other swine from 2018 was carried out, based on the Census Agriculture 2020.
The estimate of NH_3 emissions from poultry storage since 2012 has been revised to correct for manure sent to anaerobic digestion.
The estimation of EF NH_3 from cattle and swine storage was modified to introduce EF NH_3 from digester storage with open digestate tank, from 2010.
NH_3 emissions from storage have been corrected by removing from the overall estimate of NH_3 from storage only the portion of NH_3 from storage of digestate in open tank (which moves into the waste sector), for the entire time series (starts from 1991, because in 1990 anaerobic digesters were not there). In the waste sector, there will also be a share of NH_3 from feedstock used in anaerobic digesters.
An update of FE NH_3 from spreading of laying hens from 2014, sows and other swine from 2017, and cattle from 2016, based on Census Agriculture 2020, has been carried out.
The numbers of laying hens and broilers from 2020 and turkeys in the years 2017-2022 were updated.
An update of the combusted fraction of rice residues since 1990 has been carried out, which involves recalculation of NH_3 emissions from crop residues.

Changes related to NO_2 emissions are described below.

The percentages of dairy cattle and non-dairy cattle on pasture have been changed since 2007, based on data from the 2020 Agriculture Census (whose data were made available by ISTAT in 2024).
In addition, the update of NOx estimates from manure management comes from updating the breakdown between liquid and solid management system of laying hens since 2006, except for the years 2010-2019. Because NH_3 emissions from storage have been changing since 1991, as seen above, the changes in NOx emissions from storage, which according to the methodology depend on NH_3 emissions, affect the entire time series.
Changes in grazing rates and NH_3 estimates imply changes in NOx estimates at storage, spreading, and grazing.
The numbers of laying hens and broilers from 2020 and turkeys in the years 2017-2022 were updated.

Changes related to PM emissions are described below.

An update of the EF estimate for other poultry was made, based on data of the number of heads of the categories included in other poultry from the 2020 Census of Agriculture.
The numbers of laying hens and broilers from 2020 and turkeys in the years 2017-2022 were updated.

Changes related to NMVOC emissions are described below.

The percentages of dairy cows on pasture were changed from 2007, based on data from the 2020 Agriculture Census (whose data were made available by ISTAT in 2024). This change resulted in the updating of GE.
The breakdown of NMVOC emissions between liquid and solid management system since 2006 was updated based on the variation over the years between liquid and solid system of laying hens (previously, a fixed figure had been left since 2006).
The numbers of laying hens and broilers from 2020 and turkeys in the years 2017-2022 were updated.

Changes related to field burning of agricultural residues emissions are described below.

The emissions change because residue-to-grain ratios for cereals have been updated based on the internship work of Mounérat Nathan (Internship Mounérat N., 2024), starting in 2001 (the new values have been applied since 2006, and a smooth transition was estimated before). Cereal residue data from Motola *et al* (Motola V. *et al*, 2009) were processed. Based on this change, coefficients for estimating the removable residue (and consequently also the fixed residue) of cereals have been updated since 2001.
The 2022 rice production figure has been updated.
Based on these changes, there is a recalculation of emissions from stubble burning of NH_3, NMVOC, NOx, PM, BC, CO, PAH, HM, Dioxins.

6.8 PLANNED IMPROVEMENTS

In the coming years, based on regional data on livestock manure management techniques, particularly from the Po River Basin area, a review of statistical data provided by ISTAT and collected as part of the Census and triennial Farm Structure Surveys will be undertaken.

7 WASTE (NFR SECTOR 5)

7.1 OVERVIEW OF THE SECTOR

Italy estimates the categories of the waste sector, as reported in the following box. In the previous submission, Italy has reported NH_3 emissions from latrines (EEA, 2023) and PM from the disposal of mineral waste have been estimated. In the last available national census on wastewater treatment plants (ISTAT, 2015) the following data are reported: 99.4% of people are served by the sewage system, 17,897 wastewater system plants serve a total of 98,360,724 people equivalent; 8,377 are the Imhoff tanks present in Italy, 1,607 are the primary wastewater treatment plants, 5,604 are the secondary wastewater treatment plants and 2,309 are the advanced wastewater treatment plants. The biogas collected from the anaerobic digestion of wastewaters is burned with heat/energy recovery and relevant emissions are reported in Category 1 while emissions from the exceeding biogas which is flared are not estimated at the moment because emission factors are under investigation, but anyway it should be negligible.

NFR		SNAP	
5A	Solid waste disposal on land	09 04 01 09 04 02	Managed waste disposal on land Unmanaged waste disposal on land
5B	Biological treatment of waste	09 10 05 09 10 06	Compost production Anaerobic digestion at biogas facilities
5C1a	Municipal waste incineration	09 02 01	Incineration of municipal wastes
5C1b	Other waste incineration	09 02 02 09 02 05 09 02 07 09 02 08	Incineration of industrial wastes Incineration of sludge from wastewater treatment Incineration of hospital wastes Incineration of waste oil
5C1bv	Cremation	09 09 01	Cremation of corpses
5C2	Small scale waste burning	09 07 00	Open burning of agricultural wastes
5D	Wastewater handling	09 10 01 09 10 02 09 10 07	Waste water treatment in industry Waste water treatment in residential and commercial sector Dry toilets (including latrines)
5E	Other waste	09 10 XX	Car and building fires

Concerning air pollutants, emissions estimated for each sector are reported in Table 7.1.

Table 7.1 Air pollutant emissions estimated for each sector.

	5A	5B	5C1a	5C1bi	5C1bii	5C1biii	5C1biv	5C2	5C1bv	5D	5E
Main pollutants											
NO_x			x	x	x	x	x	x	x		
CO			x	x	x	x	x	x	x		
NMVOC	x	x	x	x	x	x	x	x	x	x	
SO_x			x	x	x	x	x	x	x		
NH_3	x	x	x							x	
Particulate matter											
TSP	x		x	x	x	x	x	x	x		x

	5A	5B	5C1a	5C1bi	5C1bii	5C1biii	5C1biv	5C2	5C1bv	5D	5E
PM10	x		x	x	x	x	x	x	x		x
PM2.5	x		x	x	x	x	x	x	x		x
Priority heavy metals											
Pb			x	x	x	x	x	x	x		x
Cd			x	x	x	x	x	x	x		x
Hg			x	x	x	x	x	x	x		x
POPs Annex II											
PCB			x	x		x	x		x		
POPs Annex III											
Dioxins			x	x	x	x	x	x	x		x
PAH			x	x	x	x	x	x	x		
HCB			x	x		x	x		x		
Other heavy metals											
As			x	x	x	x	x	x	x		
Cr			x	x	x	x	x	x	x		
Cu			x	x	x	x	x	x	x		
Ni			x	x	x	x	x		x		
Se			x	x		x		x	x		
Zn			x	x	x		x	x	x		

In 2023, open burning of waste (5C2) is key category for BC, Cd and CO, car and building fires (5E) is a key category for PM10, PM2.5 and dioxins emissions while clinical waste incineration (5C1biii) is key category for HCB. In 1990, municipal waste incineration (5C1a), industrial waste incineration (5C1 bi) and car and building fires (5E) are key categories for dioxins emissions. As regard the trend, municipal waste incineration (5C1a) and car and building fires (5E) are key categories for dioxins emissions, car and building fires (5E) is a key category for PM10, whereas open burning of agricultural waste (5C2) is key category for Cd emissions.

The waste sector, and in particular Waste incineration (5C), is a source of different pollutants; for the main pollutants, in 2023, the sector accounts for:

- 17.2 % in national total Dioxin emissions;
- 10.8 % in national total BC emissions;
- 10.3% in national total Cd emissions;
- 9.0 % in national total HCB emissions .

Moreover, the sector comprises 4.4% of CO, 4.1% of total PM2.5 emissions, , 3.1% of NH_3, 2.9% of PM10, 2.2% of PAH and Hg, 1.1% in national total of PCB emissions and for what concerns all remaining pollutants are below 1%.

7.2 METHODOLOGICAL ISSUES

The following paragraphs describe the estimation methodologies for each emission category, and also report the main information for the activity data and the parameters used.

7.2.1 Solid waste disposal on land (5A)

Solid waste disposal on land is a major source concerning greenhouse gas emissions but not concerning air pollutants. Notwithstanding, NMVOC and NH_3 emissions are estimated, as a percentage of methane emitted, calculated using the IPCC Tier 2 methodology (IPCC, 1997; IPCC, 2000), through the application of the First Order Decay Model (FOD). As a consequence of the last review process also PM emissions have been estimated. A detailed description of the model and its application to Italian landfills is reported in the National Inventory Document on the Italian greenhouse gas inventory (ISPRA, 2025 [a]).

The amount of biogas recovery in landfills has increased as a result of the implementation of the European Directive on the landfill of waste (EC, 1999); the amounts of biogas recovered and flared have been estimated taking into account the amount of energy produced, the energy efficiency of the methane recovered, the captation efficiency and the efficiency in recovering methane for energy purposes assuming that the rest of methane captured is flared. Emissions for all the relevant pollutants from biogas recovered from landfills and used for energy purposes are reported in the energy sector in "1A4a biomass" category together with wood, the biomass fraction of incinerated waste and biogas from wastewater plants. In Table 7.2 consumptions and low calorific values are reported for the year 2023.

Table 7.2 1A4a biomass detailed activity data. Year 2023

Fuels		Consumption (Gg)	LCV (TJ/Gg)
Wood and similar	Wood	295.41	10.47
	Steam Wood	0.00	30.80
Incinerated waste (biomass)		2210.99	11.15
Biogas from landfills		186.88	54.27
Biogas from wastewater plants		24.56	54.27

It is assumed that landfill gas composition is 50% VOC. The percentage by weight of CH_4 compared to the total VOC emitted is 98.7%. The remaining 1.3% (NMVOC) consists of paraffinic, aromatic and halogenated hydrocarbons (Gaudioso et al., 1993): this assumption refers to US EPA data (US EPA, 1990). As regard ammonia, emission factor has been assumed equal to 1 volume per cent of VOC too (Tchobanoglous et al., 1993). According with the discussion during the ESD review about CH_4 emissions from landfills and the consequent technical correction (EEA, 2017 [b]), Italy revised the half-life values considering the distribution of dry and wet regions in Italy. New data (CREA, 2017) regarding raining and evapotranspiration have been elaborated allowing to distinguish between dry and wet region and the estimates have been splitted in two components considering the location of SWDS. Methane, and consequently NMVOC and NH_3 air pollutants, is emitted from the degradation of waste occurring in municipal landfills, both managed and unmanaged (due to national legislation, from 2000 municipal solid wastes are disposed only into managed landfills). The main parameters that influence the estimation of emissions from landfills are, apart from the amount of waste disposed into managed landfill: the waste composition (which vary through the years in the model); the fraction of methane in the landfill gas (included in VOC, which has been assumed equal to 50%) and the amount of landfill gas collected and treated. These parameters are strictly dependent on the waste management policies throughout the waste streams which consist of: waste generation, collection and transportation, separation for resource recovery, treatment for volume reduction, stabilisation, recycling and energy recovery and disposal at landfill sites. Basic data on waste production and landfills systems are those provided by the national Waste Cadastre, basically built with data reported through the Uniform Statement Format (MUD). The Waste Cadastre is formed by a national branch, hosted by ISPRA, and by regional and provincial branches.

These figures are elaborated and published by ISPRA yearly since 1999: the yearbooks report waste production data, as well as data concerning landfilling, incineration, composting, anaerobic digestion and generally waste life-cycle data (APAT-ONR, several years; ISPRA, several years [a]).

For inventory purposes, a database of waste production, waste disposal in managed and unmanaged landfills and sludge disposal in landfills was created and it has been assumed that waste landfilling started in 1950. For the year 2023, the non-hazardous landfills in Italy disposed 4,613 kt of MSW and 1,970 kt of industrial wastes, as well as 58 kt of sludge from urban wastewater treatment plants. In Table 7.3, the time series of AMSW and domestic sludge disposed into non-hazardous landfills from 1990 is reported.

Table 7.3 Trend of MSW production and MSW, AMSW and domestic sludge disposed in landfills (Gg)

ACTIVITY DATA (Gg)	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
MSW production	22,231	25,780	28,959	31,664	32,479	29,524	28,941	29,618	29,051	29,262
MSW disposed in landfills for non-hazardous waste	17,432	22,459	21,917	17,226	15,015	7,819	5,817	5,619	5,173	4,613
Assimilated MSW disposed in landfills for non-hazardous waste	2,828	2,978	2,825	2,914	3,508	3,222	2,910	2,963	2,469	1,970
Sludge disposed in managed landfills for non-hazardous waste	2,454	1,531	1,326	544	346	387	253	106	64	58
Total Waste to managed landfills for non-hazardous waste	16,363	21,897	26,069	20,684	18,870	11,428	8,980	8,687	7,705	6,641
Total Waste to unmanaged landfills for non-hazardous waste	6,351	5,071	-	-	-	-	-	-	-	-
Total Waste to landfills for non-hazardous waste	22,714	26,968	26,069	20,684	18,870	11,428	8,980	8,687	7,705	6,641

7.2.2 Biological treatment of waste (5B)

Under this category, NMVOC and NH_3 emissions from compost production and from anaerobic digestion are reported. The amount of waste treated in biological treatments has shown a great increase from 1990 to 2023 (from 283,879 Mg to 6,087,151 Mg for composting and from 0 to 83,950 Mg of N-excreted from manure management). Information on input waste to composting plants is published yearly by ISPRA since 1996, including data for 1993 and 1994 (ANPA, 1998; APAT-ONR, several years; ISPRA, several years [a]), while for 1987 and 1995 only data on compost production are available (MASE, several years [a]; AUSITRA-Assoambiente, 1995); on the basis of this information the whole time series has been reconstructed. The composting plants are classified in two different kinds: the plants that treat a selected waste (food, market, garden waste, sewage sludge and other organic waste, mainly from the agro-food industry) and the mechanical-biological treatment plants, that treat the unselected waste to produce compost, refuse derived fuel (RDF), and a waste with selected characteristics for landfilling or incinerating system. It is assumed that 100% of the input waste to the composting plants from selected waste is treated as compost, while in mechanical-biological treatment plants 30% of the input waste is treated as compost on the basis of national studies and references (Favoino and Cortellini, 2001; Favoino and Girò, 2001). NMVOC emission factor (51g NMVOC kg-1 treated waste) is from international scientific literature too (Finn and Spencer, 1997).

In Italy, almost all of the plants are industrial plants, with enclosed areas for rotting and decomposition served by biofilters, turning when needed to maintain the right porosity and, above all, forced ventilation or suction system at least since the 2000s also because requested by regional law. To ensure high quality compost the CIC (Consorzio Italiano Compostatori) introduced a few years ago a certification procedure that, in 2014, covers the 28% of national capacity regarding compost from selected waste (ISPRA, 2017). As reported in (ISPRA, 2017 Update of CH_4 emission factor from composting. Technical note n.1/2017), the plant engineering framework in Italy is very advanced being characterized by industrial scale plants and the technical requirements and specific air supplies normally required in environmental permits typically consider a high excess of air, as only 10% of the flow of air required corresponds to the stoichiometric quantity for biodegradation while the remaining 90% is required for heat drainage so that the system is maintained in mesophilic conditions; naturally, the excess oxygen in the atmosphere inside the compost heaps tends to keep the system fundamentally aerobic and to avoid specific methane production. This plant framework was made possible by the regulations that supported it since the early 2000s, while less information was available in the 90s. To satisfy the request of the review process (EEA, 2023) the penetration rate of abatement technologies has been introduced. As reported in the already cited Technical note n.1/2017, Italian plants were already quite advanced between the years 2000 and 2010. Consequently, the default EF (0.24 kg/Mg) has been applied from 1990 to 2000 while starting from 2010 the abated EF (0.024 kg/Mg) has been applied. Between 2001 and 2009 linear smoothing has been applied.

Data for N contained in livestock manure (sent to digesters) have been updated: for cattle since 2007 and for other poultry since 2012. For cattle, this change comes from updating the percentages of grazing livestock based on the 2020 Census of Agriculture. For other poultry, the change would start from 2010, but the share of poultry manure was started to anaerobic digestion from 2012. These emissions have been subtracted from 3B manure management category (cattle, swine and poultry) and allocated in the anaerobic digestion at biogas facilities (5B2 of the waste sector).

7.2.3 Waste Incineration (5C1a – 5C1b)

Regarding waste incineration, methodology used for estimating emissions is based on and consistent with the EMEP/CORINAIR Guidebook (EMEP/EEA, 2019). In this sector only emissions from facilities without energy recovery are reported, whereas emissions from waste incineration facilities with energy recovery are reported in the Energy Sector 1A4a because energy produced in incinerators is still prevalently used to satisfy the internal energy demand of the plants (auto production) and in this sense it would be wrong, according to the guidelines, to report them under 1A1a Public Electricity and Heat Production instead of 1A4a. In 2023, about 99% of the total amount of urban waste incinerated is treated in plants with energy recovery system. Existing incinerators in Italy are used for the disposal of municipal waste, together with some industrial waste, sanitary waste and sewage sludge for which the incineration plant has been authorized by the competent authority. Other incineration plants are used exclusively for industrial and sanitary waste, both hazardous and not, and for the combustion of waste oils, whereas there are plants that treat residual waste from waste treatments, as well as sewage sludge.

A complete database of the incineration plants is now available, updated with the information reported in the yearly report on waste production and management published by ISPRA (APAT-ONR, several years; ISPRA, several years). For each plant a lot of information is reported, among which the year of the construction and possible upgrade, the typology of combustion chamber and gas treatment section, energy recovery section (thermal or electric), and the type and amount of waste incinerated (municipal, industrial, etc.). A specific emission factor is therefore used for each pollutant combined with plant specific waste activity data.

In Table 7.4, emission factors for each pollutant and waste typology are reported. Emission factors have been estimated on the basis of a study conducted by ENEA (De Stefanis P., 1999), based on emission data from a large sample of Italian incinerators (FEDERAMBIENTE, 1998; AMA-Comune di Roma, 1996), legal thresholds (Ministerial Decree 19 November 1997, n. 503 of the Ministry of Environment; Ministerial Decree 12 July 1990) and expert judgements. Since 2010, emission factors for urban waste incinerators have been updated on the basis of data provided by plants (ENEA-federAmbiente, 2012; De Stefanis P., 2012) concerning the annual stack flow, the amount of waste burned and the average concentrations of the pollutants at the stack. As the emission factors are considerably lower than the old ones due to the application of very efficient abatement systems it was necessary to apply a linear smoothing methodology assuming a progressive application of the abatement systems between 2005 and 2010. In a similar way, emission factors for industrial waste incinerators have been updated from 2010 onwards on the basis of the 2019 EMEP/EEA Guidebook. Similarly to municipal waste smoothing has been applied between 2005 and 2010 supposing a linear application of the abatement systems. In particular, for 5C1bi the HCB emission factors come from table 3-1 of the 2019 EMEP/EEA Guidebook considering an abatement efficiency of 90% while PCB emission factors derives from 2007 Guidebook but considering 90% abatement (no value in the 2019 EMEP/EEA Guidebook). For 5C1biii the emission factors from 2019 EMEP/EEA Guidebook have been used for PCB while HCB emission factors derive from 2007 Guidebook because of a lack of information in the last guidebook. For 5C1biv emission factors from 2019 EMEP/EEA Guidebook have been considered without abatement because information about this specific category of plant is under investigation.

Table 7.4 Emission factors for waste incineration

Air Pollutant	u.m.	Municipal 1990-2009	Municipal since 2010	Industrial 1990-2009	Industrial since 2010	Clinical 1990-2009	Clinical since 2010	Sludge 1990-2009	Sludge since 2010	Oil 1990-2009	Oil since 2010
NO_x	kg/t	1.15	0.62	2.00	2.00	0.60	0.60	3.00	3.00	2.00	2.00
CO	kg/t	0.07	0.07	0.56	0.56	0.08	0.08	0.60	0.60	0.08	0.08
NMVOC	kg/t	0.46	0.46	7.40	7.40	0.70	0.70	0.25	0.25	7.40	7.40
SO_2	kg/t	0.39	0.02	1.28	1.28	0.03	0.03	1.80	1.80	1.28	1.28
PM10	g/t	46.00	6.06	240.00	7.00	25.68	25.68	180.00	41.00	240.00	0.07
PM2.5	g/t	30.89	4.07	240.00	4.00	25.68	25.68	180.00	11.00	240.00	0.04
As	g/t	0.05	0.02	0.12	0.00	0.00	0.00	0.50	0.24	0.12	0.00
Cu	g/t	1.00	0.00	1.20	0.12	0.56	0.56	10.00	2.00	1.20	0.01
Se	g/t	0.01	0.01	0.01	0.00	0.04	0.04	-	0.01	0.01	0.00
Zn	g/t	0.02	0.02	12.60	1.26	-	-	10.00	3.30	12.60	0.13
Cd	g/t	0.25	0.01	0.80	0.01	0.00	0.00	1.20	0.80	0.80	0.00
Cr	g/t	0.45	0.00	1.60	0.16	0.01	0.01	3.00	0.70	1.60	0.02
Hg	g/t	0.15	0.03	0.80	0.01	0.04	0.04	1.20	1.15	0.80	0.01
Ni	g/t	16.35	0.00	0.80	0.01	0.03	0.03	3.00	0.40	0.80	0.00
Pb	g/t	1.35	1.04	24.00	0.13	0.02	0.02	3.00	0.40	24.00	0.01
PAH	g/t	0.05	0.00	0.48	0.00	0.00	0.00	0.60	0.00	0.48	0.00
PCB	g/t	0.005	0.00005	0.0050	0.0005	0.020	0.020	0.005	0.0045	-	-
HCB	g/t	0.001	0.00002	0.0001	0.0002	0.019	0.019	0.500	0.0047	-	-
NH_3	g/t	3.00	3.00	-	-	-	-	-	-	-	-

Concerning dioxin emissions, clinical and industrial emission factors are also derived from data collected from a large sample of Italian incinerators and legal thresholds, as well as expert judgement; in particular for municipal solid waste, emission factors vary within the years and the facility on the basis of plant technology (i.e. typology of combustion chamber and gas treatment section) and the year of the upgrade.

This site specific evaluation has been possible thanks to a study conducted in the past for a sample of municipal waste incinerators located in Regione Lombardia in order to produce an assessment of field-based values applicable to other facilities with the same characteristics (Pastorelli et al., 2001) and, since 2010 urban waste data, thanks to the abovementioned survey (ENEA-federAmbiente, 2012). Moreover, for the incineration plants reported in the national EPER/PRTR register, verification of emissions has been carried out. In Table 7.5 dioxin emission factors for waste incineration are reported for 1990 and 2023.

Table 7.5 Dioxin emission factors for 1990 and 2023

Waste Typology	u.m	1990	2023
Municipal	g/t	115 - 1.6	0.116
Clinical	g/t	200	0.500
Industrial	g/t	80 - 135	0.500
Sludge	g/t	77	0.500
Oil	g/t	200	0.500

In Table 7.6 activity data are reported by type of waste.

Table 7.6 Amount of waste incinerated by type (Gg)

Waste incinerated	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Gg					
Total waste	1,656.2	2,149.1	3,061.7	4,964.2	6,950.2	7,534.6	7,479.6	7,484.1	7,223.7	7,611.9
with energy recovery	911.2	1,557.8	2,749.7	4,720.6	6,768.8	7,431.3	7,409.7	7,373.5	7,125.8	7,511.3
without energy recovery	745.0	591.3	312.0	243.5	181.4	103.2	69.8	110.6	98.0	100.6
Municipal waste (5C1a)	1,025.6	1,436.6	2,324.9	3,219.9	4,336.9	4,698.4	4,227.2	4,304.9	4,161.7	4,422.0
with energy recovery	626.4	1,185.5	2,161.4	3,168.0	4,284.0	4,698.4	4,227.2	4,304.9	4,161.7	4,422.0
without energy recovery	399.2	251.1	163.5	51.9	52.9	0.0	0.0	0.0	0.0	0.0
Industrial waste (5C1b i-ii-iv)	496.1	560.7	626.5	1,618.1	2,478.2	2,734.6	3,145.0	3,065.0	2,962.4	3,087.6
with energy recovery	259.5	331.2	511.6	1,447.0	2,372.3	2,676.0	3,119.0	3,005.2	2,914.9	3,038.8
without energy recovery	236.6	229.6	114.8	171.1	105.9	58.6	25.9	59.8	47.6	48.8
Clinical waste (5C1biii)	134.5	151.7	110.3	126.2	135.1	101.6	107.4	114.1	99.6	102.3
with energy recovery	25.3	41.1	76.7	105.7	112.5	57.0	63.5	63.3	49.2	50.5
without energy recovery	109.2	110.6	33.6	20.5	22.6	44.6	43.9	50.8	50.4	51.7

7.2.4 Cremation of corpses (5C1bv)

Emissions from incineration of human bodies in crematoria have been carried out for the entire time series. The methodology used for estimating emissions is based on and conform to the EMEP/EEA Air Pollutant Emission Inventory Guidebook (EMEP/EEA, 2023).

Activity data have been supplied by a specific branch of Federutility, which is the federation of energy and water companies (SEFIT, several years), whereas emission factors derive from a survey carried out by the same subject in 2015 and in 2019. For some metal, such as Pb, Cd, As, Cr, Cu, Ni and Se EFs are those reported in the Guidebook 2023. Up to some years ago cremation was not so popular in Italy also because the Catholic Church encouraged burial. Partly because cemeteries are becoming overcrowded, in addition to Covid emergency, the number of cremations in Italy has risen from 5,809 in 1990 to 252,075 in 2023, higher than the peak value of 247,840 in 2020 but slightly down compared to the 2022 figure. Moreover, it is practice cremating also mortal remains: activity data have been supplied too by SEFIT, from 1999, whereas mortal remains from 1990 to 1998 have been reconstructed on the basis of an expert judgment (SEFIT, several years).

In Table 7.7 time series of number of cremations, mortal remains, as well as annual deaths and crematoria in Italy are reported. The major emissions from crematoria are nitrogen oxides, carbon monoxide, sulphur dioxide, particulate matter, mercury, hydrogen fluoride (HF), hydrogen chloride (HCl), NMVOCs, other heavy metals, and some POPs. As a consequence of the review process, mortal remains time series has been revised: mortal remains have been converted into corpses equivalents, multiplying data for 75/90 ratio, according with national experts (Sefit, 2022), based on the average time of cremation (90 minutes for a corpse and 75 minutes for a mortal remain. In Table 7.8 emission factors for cremation 2023 are reported.

Table 7.7 Cremation time series (activity data)

Cremation of corpses	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Cremations	5,809	15,436	30,167	48,196	77,379	137,168	247,840	244,186	259,915	252,075
Deaths	543,700	555,203	560,241	567,304	587,488	653,000	746,146	709,035	713,499	660,600
Mortal remains	1,000	1,750	1,779	9,880	18,899	34,178	29,266	45,959	45,986	44,210
% of cremation	1.07	2.78	5.38	8.50	13.17	21.01	33.22	34.44	36.43	38.16
Crematoria	ND	31	35	43	53	70	87	89	91	91

Table 7.8 Emission factors for cremation of corpses - 2023

Air pollutant	u.m.	Cremation
NO_x	kg/body	0.4739
CO	kg/body	0.0047
NMVOC	kg/body	0.0091
SO_x	kg/body	0.0093
PM10	g/body	2.1483
PM2.5	g/body	2.1483
Pb	mg/body	30.0300
Cd	mg/body	5.0300
Hg	mg/body	0.0070
As	mg/body	13.6100
Cr	mg/body	13.5600
Cu	mg/body	12.4300
Ni	mg/body	17.3300
PAH (benzo(a)pyrene)	µg/body	176.2000

Air pollutant	u.m.	Cremation
Dioxins	µg/body	0.0190

7.2.5 Small scale waste burning (5C2)

The open burning of agricultural waste is a key category for Cd, BC and CO emissions. NMVOC, CO, NO_X, NH_3, SO_2, PM10, PM2.5, BC, As, Cr, Cu, Ni, Se, Zn, Pb, Cd, Hg, Dioxin and PAH emissions have been estimated, applying the tier 1 and tier 2 approach (for heavy metals, PAH emissions and BC). No estimations were performed for NH_3 emissions as well as other POPs. In the current submission EFs used for field burning, open burning of agricultural waste and fires have been made coherent and updated on the basis of the 2023 EMEP/EEA Guidebook and the 2006 IPCC Guidelines. This survey regarded CO, CH_4, NMVOC, NO_X, NH_3, N_2O, SO_2, PM, dioxins and PAH.

A country-specific methodology has been used. Parameters taken into consideration are the following:

1. Amount of removable residues (t), estimated with annual crop production (ISTAT, several years [a], [b]; ISTAT, 2017 [a], [b]) and removable residues/product ratio (IPCC, 1997; CESTAAT, 1988; Borgioli E., 1981).

2. Amount of dry residues in removable residue (t dry matter), calculated with amount of removable fixed residues and fraction of dry matter (IPCC, 1997; CESTAAT, 1988; Borgioli E., 1981).

3. Amount of removable dry residues oxidized (t dry matter), assessed with amount of dry residues in the removable residues, burnt fraction of removable residues (CESTAAT, 1988) and fraction of residues oxidized during burning (IPCC, 1997).

4. Amount of carbon from removable residues burning release in air (t C), calculated with the amount of removable dry residue oxidized and the fraction of carbon from the dry matter of residues (IPCC, 1997; CESTAAT, 1988).

5. $C\text{-}CH_4$ from removable residues burning (t $C\text{-}CH_4$), calculated with the amount of carbon from removable residues burning release in air and emission factor equal to 4.7g/kg dry matter burnt (IPCC, 2006).

6. C-CO from removable residues burning (t C-CO), calculated with the amount of carbon from removable residues burning release in air and emission factor equal to 107g/kg dry matter burnt (IPCC, 2006).

7. Amount of nitrogen from removable residues burning release in air (t N), calculated with the amount of removable dry residue oxidized and the fraction of nitrogen from the dry matter of residues. The fraction of nitrogen has been calculated considering raw protein content from residues (dry matter fraction) divided by 6.25.

8. $N\text{-}NO_X$ from removable residues burning (t $N\text{-}NO_X$), calculated with the amount of nitrogen from removable residues burning release in air and emission factor equal to 3 g/kg dry matter burnt (IPCC, 2006).

NMVOC emissions have been considered equal to CH_4 emissions. As regards the other pollutants, heavy metals, Dioxin and PAH emission factors are from the EMEP/EEA Guidebook (EMEP/EEA, 2016) and emissions have been added as requested by the NECD review process (EEA, 2018) (Table 7.9).

Table 7.9 Emission factors for burning of agriculture residues

Air pollutant	u.m.	Removable residues				References
		Wheat	Barley	Maize	Rice	
Benzo(a)pyrene	g/t	0.393	0.771	7.162	0.072	

Air pollutant	u.m.	Removable residues				References
		Wheat	Barley	Maize	Rice	
Benzo(b)fluoranthene	g/t	1.097	2.398	3.495	0.120	EMEP/EEA, 2023
Benzo(k)fluoranthene	g/t	0.468	0.601	2.138	0.088	
Indeno(1,2,3-cd)pyrene	g/t	0.336	0.298	2.415	0.055	
PM10	g/t	3.3				EMEP/EEA, 2023
PM2.5	g/t	2.8				EMEP/EEA, 2023
Dioxins	g/t	10				EMEP/EEA, 2023
BC	g/t	1.2				EMEP/EEA, 2013

Removable residues from agriculture production are estimated for each crop type (cereal, green crop, permanent cultivation) taking into account the amount of crop produced, from national statistics (ISTAT, several years [a], [b]; ISTAT, 2017 [a], [b]), the ratio of removable residue in the crop, the dry matter content of removable residue, the ratio of removable residue burned, the fraction of residues oxidised in burning, the carbon and nitrogen content of the residues. Most of these wastes refer especially to the prunes of olives and wine, because of the typical national cultivation. Activity data (agricultural production) used for estimating burning of agriculture residues are reported in Table 7.10. Emissions due to stubble burning, which are emissions only from the agriculture residues burned on field, are reported in the agriculture sector, under 3.F. Under the waste sector the burning of removable agriculture residues that are collected and could be managed in different ways (disposed in landfills, used to produce compost or used to produce energy) is reported. Different percentages of the removable agriculture residue burnt for different residues are assumed, varying from 10% to 90%, according to national and international literature. Moreover, these removable wastes are assumed to be all burned in open air (e.g. on field), taking in consideration the highest available CO, NMVOC, PM and dioxins emission factors as reported in the table above. The amount of biomass from pruning used for domestic heating is reported in the energy sector in the 1A4b category as biomass fuel.

Table 7.10 Time series of crop productions (Gg)

Production	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
	Gg									
Cereals										
Wheat	8,108.5	7,946.1	7,427.7	7,717.1	6,849.9	7,394.5	6,553.9	7,118.3	6,449.8	6,727.8
Rye	20.8	19.8	10.3	7.9	13.9	13.2	11.5	10.9	11.4	11.0
Barley	1,702.5	1,387.1	1,261.6	1,214.1	944.3	955.1	1,090.6	1,059.8	1,124.3	1,158.8
Oats	298.4	301.3	317.9	429.2	288.9	261.4	242.7	233.5	242.3	225.6
Rice	1,290.7	1,320.9	1,245.6	1,444.8	1,574.3	1,505.8	1,530.9	1,496.5	1,273.2	1,383.7
Maize	5,863.9	8,454.2	10,139.6	10,427.9	8,495.9	7,073.9	6,771.1	6,060.2	4,681.9	5,331.3
Sorghum	114.2	214.8	215.2	184.9	275.6	294.2	361.7	223.5	191.2	239.2
Woodycrops										
Grapes	8,438.0	8,447.7	8,869.5	8,553.6	7,839.7	7,915.0	8,222.4	8,149.4	8,438.0	6,668.8

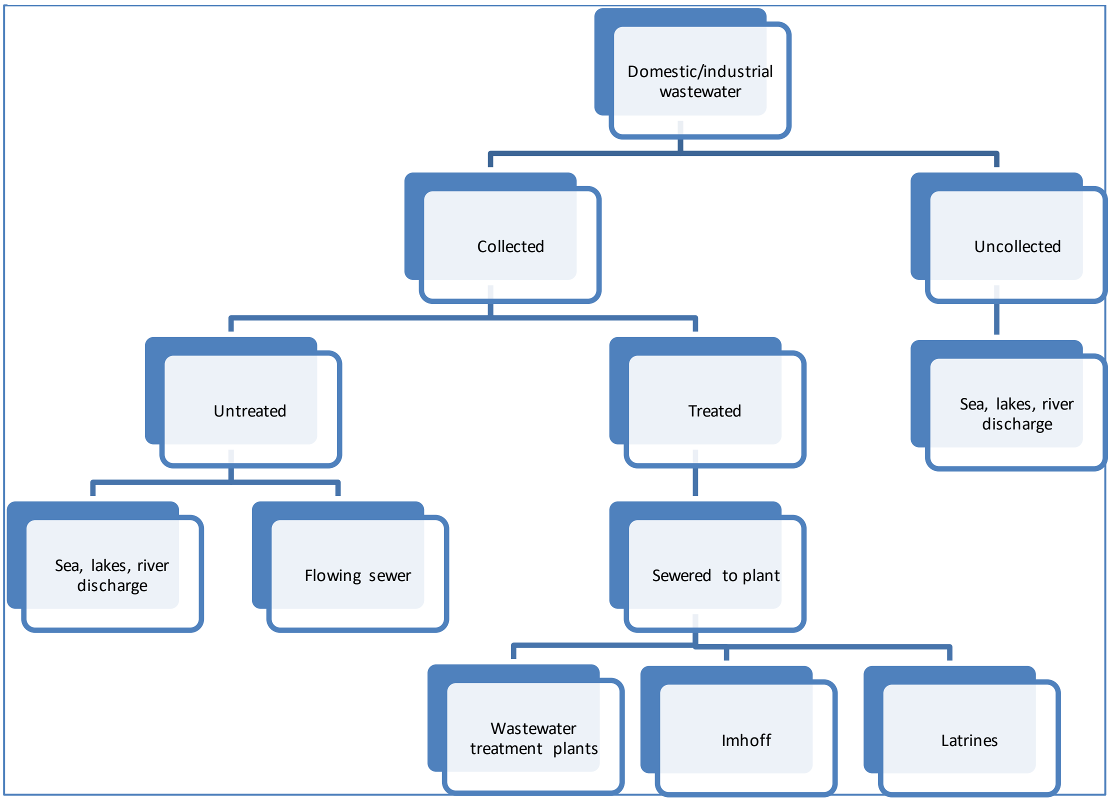
Production	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Gg					
Olives	912.5	3,323.5	2,810.3	3,774.8	3,117.8	2,732.9	2,207.2	2,270.6	2,160.4	2,397.9
CitrusOrchards	2,868.8	2,607.7	3,100.2	3,518.1	3,820.6	3,151.5	2,940.0	3,098.0	3,094.4	3,179.7
Orchards	5,793.5	5,406.6	5,952.2	6,034.5	5,777.3	5,988.8	5,408.7	4,602.1	5,301.7	4,744.4
Carobs	29.2	44.4	38.1	31.7	25.3	31.5	36.9	37.6	35.6	35.7
Total	**35,441.0**	**39,474.0**	**41,388.0**	**43,338.6**	**39,023.4**	**37,317.9**	**35,377.5**	**34,360.4**	**33,004.1**	**32,103.9**

Recalculations occur in this submission because residue-to-grain ratios for cereals have been updated based on the internship work of Mounérat Nathan (Internship Mounérat N., 2024), starting in 2001 (the new values have been applied since 2006, and a smooth transition was estimated before). Cereal residue data from Motola *et al* (Motola V. *et al*, 2009) were processed. Based on this change, the coefficients for estimating the removable residue (and consequently also the fixed residue) of cereals have been estimated since 2001.

7.2.6 Wastewater treatments (5D)

Under source category 5D, NMVOC emissions are estimated both from domestic and industrial wastewater and NH_3 emissions are estimated form latrines. In Italy, domestic wastewaters follow the treatment systems and discharge pathways reported in the following figure. Commercial and some industrial wastewaters assimilated to municipal flows are co-discharged with domestics.

Figure 7.1 Domestic wastewater treatment system and discharge pathways



In urban areas, domestic wastewaters are collected and treated in pants mainly using a secondary treatment, with aerobic biological units: a wastewater treatment plant standard design consists of bar racks, grit chamber, primary sedimentation, aeration tanks (with return sludge), settling tank, chlorine contact chamber. The stabilization of sludge occurs in aerobic or anaerobic reactors; where anaerobic digestion is used, the reactors are covered and provided of gas recovery. The biogas collected from the anaerobic digestion of wastewaters is burned with heat/energy recovery and relevant emissions are reported in the energy sector. On the contrary, in rural areas, wastewaters are treated in Imhoff tanks or in other on-site systems, such as latrines.

Industrial wastewaters are produced from most production industries like food and beverage, cloth and shoe production, paper and heavy production sites such as mining, oil and gas, as well as chemical manufacturing. Industrial wastewaters have very variable quality and volume depending on the type of industry producing and cannot be assimilated to domestic wastewaters, thus they are treated in specific plants, usually located within the industrial area.

By using EFs from the 2023 EEA/EMEP Guidebook both for domestic and industrial wastewater and the volumes of wastewater handled, NMVOC emissions resulted in the time series reported in the table below (Table 7.12). Volume of domestic wastewater is calculated starting from the inhabitants' equivalent treated in wastewater treatment plants multiplied by the average per capita water supply. For industrial wastewater, data has been collected for several industrial sectors (iron and steel, refineries, organic chemicals, food and beverage, paper and pulp, textiles and leather industry). The volume of wastewater production, for each industry selected, has been calculated multiplying the annual production (t $year^{-1}$) by the amount of wastewater consumption per unit of product (m^3 t^{-1}), as reported in following Table 7.11.

Table 7.11 Volume of wastewater production in industry

	Wastewater generation (m^3/t)	References
Coke	1.5	IPCC, 2000
Organic Chemicals	22.3	FEDERCHIMICA, several years
Paints	5.5	IPCC, 2000
Plastics and Resins	0.6	IPCC, 2000
Soap and Detergents	3	IPCC, 2000
Vegetables, Fruits and Juices	20	IPCC, 2000
Sugar Refining	4	ANPA-ONR, 2001
Vegetable Oils	3.1	IPCC, 2000
Dairy Products	3.87	ANPA-ONR, 2001
Wine and Vinegar	3.8	ANPA-ONR, 2001
Beer and Malt	420 (l/hl)	Assobirra, several years
Alcohol Refining	24	IPCC, 2000
Meat and Poultry	13	IPCC, 2000
Fish Processing	13	same value of Meat and Poultry
Paper	25	Assocarta, several years
Pulp	25	Assocarta, several years
Textiles (dyeing)	60	IPCC, 1995
Textiles (bleaching)	350	IPCC, 1995
Leather	0.12	UNIC, several years

In Table 7.12 NH_3 emissions are reported from domestic wastewater. An in-depth analysis of national circumstances has been made, collecting many statistical data on population and on urban wastewater treatment plants (BLUE BOOK, several years; COVIRI, several years; ISTAT, 1984; ISTAT, 1987; ISTAT, 1991; ISTAT, 1993; ISTAT [a], [b], 1998; ISTAT [d], [e], several years). Some data, such as the degree of collected or treated wastewater are available for specific year, so the entire time series has been reconstructed with interpolation of data. In 2023, the 99.6% of population is served by sewer systems, whereas 92% of population is served by wastewater treatment plants. In 1990, the percentage of population served by sewer system was 57%, whereas only 52% of population was served by wastewater treatment plants.

Rural population, for national circumstances, is intended as the population in "dispersed houses". Within this category (population living in "dispersed houses"), those covered by a local sewer systems, are treated only in Imhoff systems and latrines, not in WWTPs, thus activity data for calculation of NH_3 emissions are derived from the difference of rural population collected, minus rural population treated in Imhoff tanks: it is assumed that all the wastewater treated in other systems than the Imhoff is treated in latrines, consistently with the approach used to estimate GHG.

Table 7.12 Time series of NMVOC and NH_3 emissions (Gg).

NMVOC	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Domestic wastewater										
Equivalent inhabitants (*1000)	46,436	60,015	65,601	73,426	76,847	75,239	91,124	92,532	93,940	95,348
Domestic wastewaters production (10^6 m^3)	4,237	4,237	4,237	4,237	4,237	4,237	4,237	4,237	4,237	4,237
Per capita water supply (lt./person*die)	250	250	250	250	250	250	250	250	250	250
EF (mg/m^3)	15	15	15	15	15	15	15	15	15	15
NMVOC Emissions (t)	63.6	82.1	89.8	100.5	105.2	103.0	124.7	126.7	128.6	130.5
Industrial wastewater										
Industrial wastewaters production (1000 m^3)	908,840	928,479	920,614	867,085	717,846	659,246	654,586	701,388	676,516	637,366
EF (mg/m^3)	15	15	15	15	15	15	15	15	15	15
NMVOC Emissions (t)	13.6	13.9	13.8	13.0	10.8	9.9	9.8	10.5	10.1	9.6
NH3	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**	**2022**	**2022**
Domestic wastewater										
Rural population (*1000)	3,831	3,710	3,589	3,422	3,347	3,225	3,104	3,080	3,056	3,032
Population not served by collecting systems	1,647	1,120	502	582	330	19	15	14	13	12
Population served by collecting systems	2,184	2,590	3,087	2,840	3,016	3,206	3,090	3,066	3,043	3,019
treated in Imhoff tanks	421	647	845	468	635	967	1,174	1,192	1,210	1,229
treated in latrines	1,763	1,943	2,242	2,373	2,381	2,239	1,915	1,874	1,832	1,791
EF (kg/person/year)	1.6	6.6	11.6	16.6	21.6	26.6	31.6	32.6	33.6	34.6
NH_3 Emissions (t)	2,821	2,821	2,821	2,821	2,821	2,821	2,821	2,821	2,821	2,821

7.2.7 Other waste (5E)

On the basis of the Final review report of the 2017 Comprehensive technical review of national emission inventories (EEA, 2017 [a]) emissions from category 5E – Car and Building Fires have been estimated. Buildings have been subdivided into 4 subcategories: detached house, undetached house, apartment buildings and industrial buildings and the distribution of population in the different typology of building has been derived from Eurostat. Data regarding the number of car and building fires have been derived from the Annually statistics of fire service in Italy (Annually statistics of fire service in Italy, several years) while EFs are coherent with the Guidebook EMEP/EEA 2016 deriving from Aasestad, 2007 for particulate matter (TSP=PM10=PM2.5) while BC EF has been derived from IIASA report (IIASA, 2004). No data about car and building fires are available before 2000 so 90's data have been reconstructed on the basis of the national population and the resulting time series are reported in Table 7.13. On the basis of the recent review reports (EEA, 2019; EEA, 2020; EEA 2021) PCDD/F emissions have been estimated and revised. After the technical correction during the 2019 NECD review, Italy investigated emission factors because those reported in the guidebook seems to be unreliable or not fitting to the Italian context. In particular, the emission factors reported in the EMEP/EEA Guidebook "used for particles in the inventory are given by scaling the emission factors used for combustion of fuelwood in the households" (Aasestad, 2007) but the Italian buildings are made up of the vast majority of reinforced concrete. Despite this, following the last review process, Italy decided to use these emission factors pending the availability of values deriving from new studies. Further, Cd, Hg and Pb emissions have been estimated for this source on the basis of 2019 EMEP/EEA Guidebook.

Table 7.13 PM2.5 and BC emissions from the category 5E

	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Detached house fires (n°)	10,580	10,592	10,614	10,861	9,213	9,577	13,554	14,174	13,151	12,747
Undetached house fires (n°)	8,186	8,195	8,212	8,404	6,928	11,484	12,078	12,685	12,378	11,357
Apartment building fires (n°)	18,843	18,865	18,904	19,344	18,891	23,278	29,020	32,695	33,980	33,897
Industrial building fires (n°)	4,931	4,936	4,947	5,062	4,560	4,872	3,192	3,278	4,128	3,985
Car fires (n°)	25,924	25,954	26,008	26,614	22,735	22,680	18,641	19,270	19,901	20,924
5E PM2.5 (Gg)	3.04	3.05	3.05	3.13	2.76	3.29	4.09	4.39	4.30	4.17
5E BC (Gg)	0.56	0.56	0.57	0.58	0.51	0.61	0.76	0.81	0.80	0.77
5E PCDD/F (g Iteq)	31.18	31.21	31.28	32.01	28.20	33.56	41.53	44.47	43.63	42.39
Cd (t)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hg (t)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02
Pb (t)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02

7.3 TIME SERIES AND KEY CATEGORIES

The following Table 7.14 presents an outline of the weight of the different categories for each pollutant in the waste sector for the year 2023. Key categories are those shaded in blue.

Table 7.14 Key categories in the waste sector in 2023

	5A	5B1	5B2	5C1bi	5C1biii	5C1biv	5C1bv	5C2	5D1	5D2	5E
						%					
SO_x				0.06	0.002	0.04	0.00	0.13			
NO_x				0.01	0.006	0.01	0.02	0.39			
NH_3	1.56	0.04	0.76						0.75		
NMVOC	0.85	0.04		0.03	0.00	0.000	0.0003	0.02	0.01	0.00	
CO				0.001	0.0002	0.001	0.000	4.36			
PM10	0.001			0.000	0.0007	0.000	0.000	0.80			2.11
PM2.5	0.0002			0.00	0.0010	0.000	0.000	1.08			3.00
BC				0.000	0.0003	0.0000		6.20			4.60
Pb				0.00	0.0006	0.00	0.004270	0.08			0.01
Cd				0.01	0.0014	0.31	0.03494	9.65			0.29
Hg				0.00	0.04	0.35	0.038	1.34			0.46
PAH				0.00	0.000012	0.00	0.000083258	2.15			
Dioxins				0.01	0.009	0.003	0.002	2.95			14.26
HCB				0.05	8.20	0.63	0.07				
PCB				0.02	0.98	0.07	0.02				

Note: key categories are shaded in blue

The following pie charts show, for the main pollutants, the contribution of each sub-category to the total emissions from the waste sector, both for 1990 and 2023 (Figure 7.2, Figure 7.3, Figure 7.4 and Figure 7.5).

Finally, in Table 7.15, emissions time series for each pollutant of the waste sector are reported. In the period 1990-2023, total emissions from incineration plants increase, but whereas emissions from plants with energy recovery show a strong growth, emissions from plants without energy recovery decreased because of the legal constraints which impose the energy production. For 2023, about 99% of the total amount of urban waste incinerated is treated in plants with energy recovery system reported in 1A4a.

On the basis the NEC review (EEA, 2022) Italy took in consideration the review of PM emissions from landfills and made a survey on possible activity data and, above all, emission factors. In the previous submission estimates have been carried out.

Figure 7.2 Contribution of CO, NOX and NMVOC sub-category emissions to waste sector total emissions

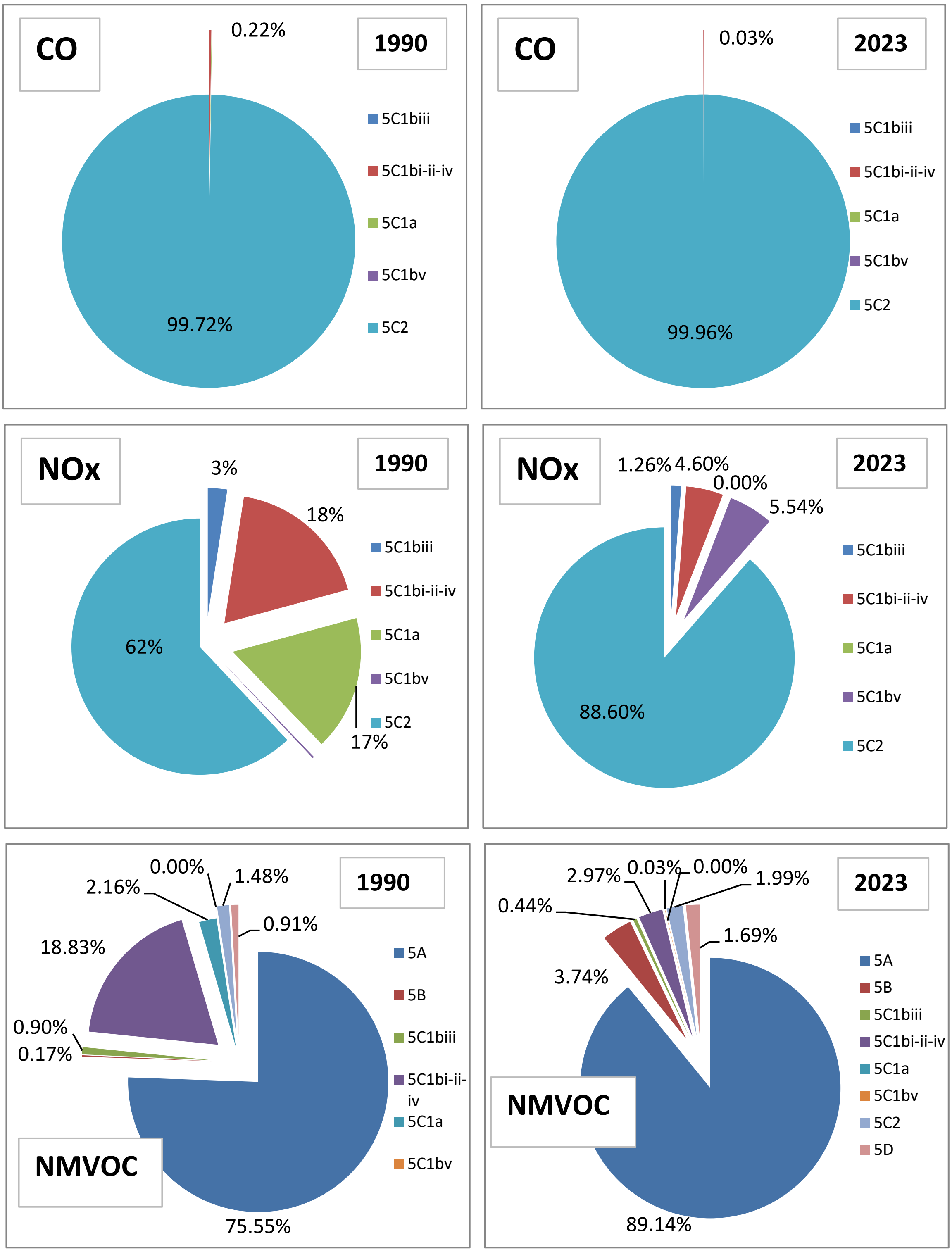


Figure 7.3 Contribution of POPs Annex III sub-category emissions to waste sector total emissions

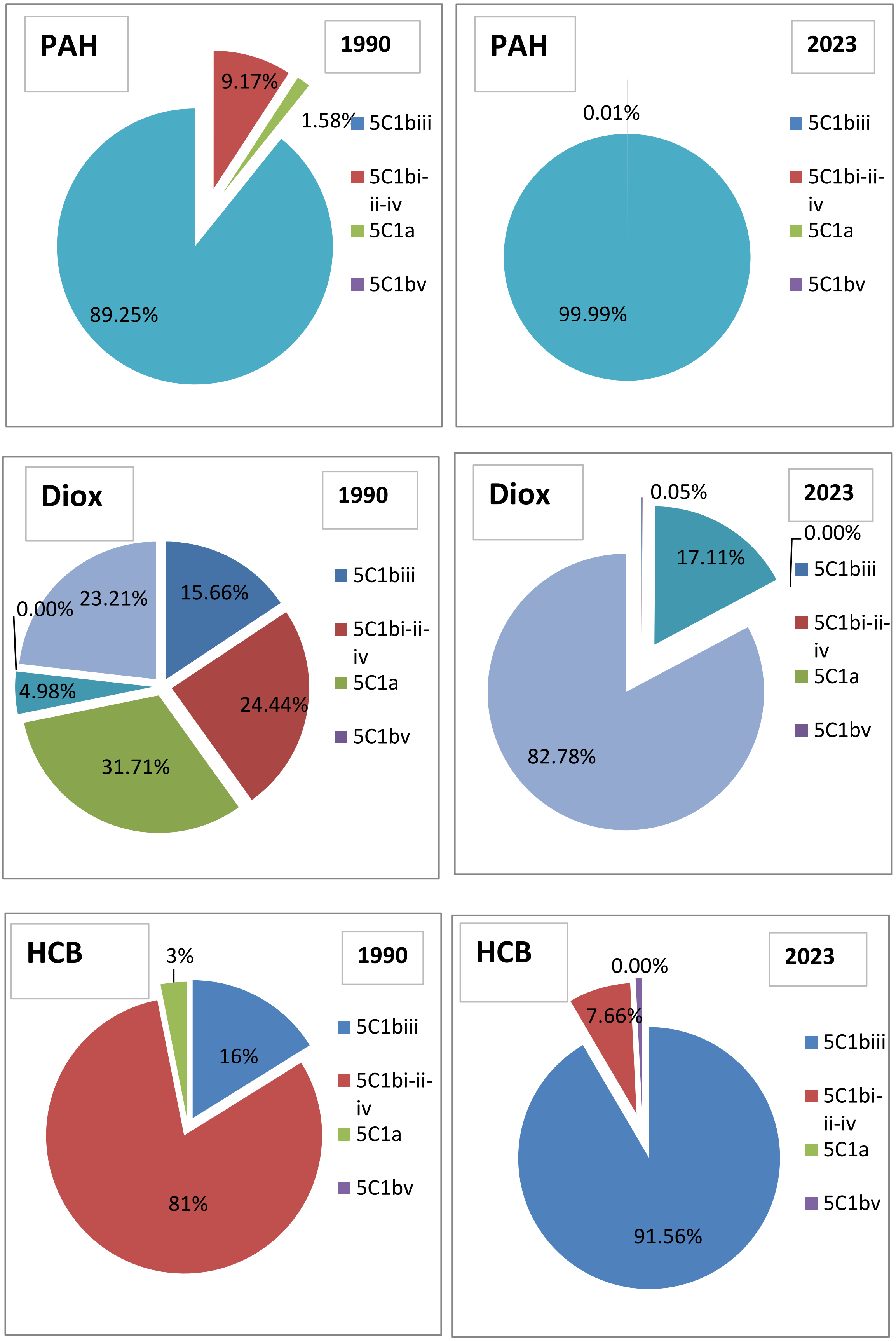


Figure 7.4 Contribution of priority heavy metals sub-category emissions to waste sector total emissions

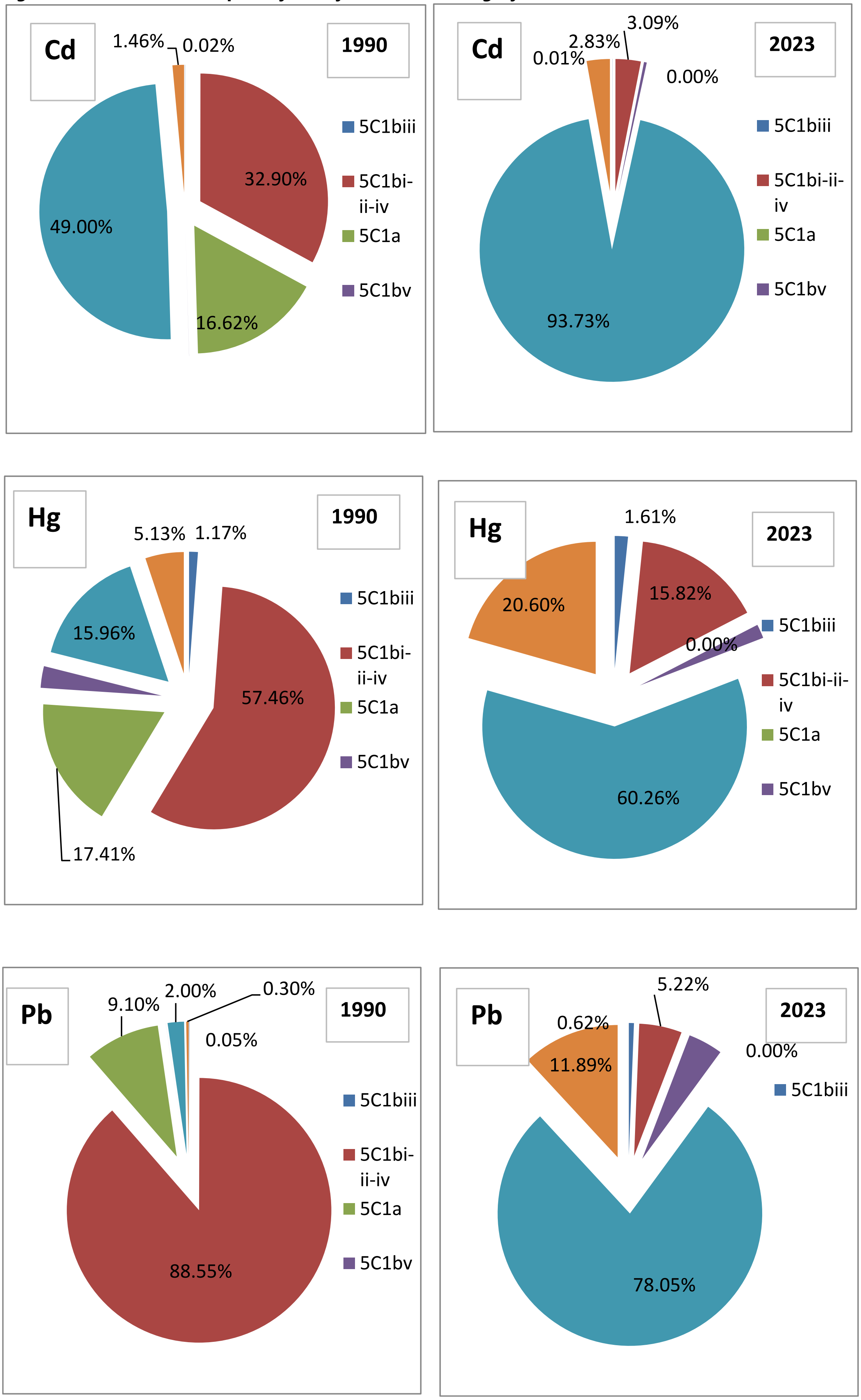


Figure 7.5 Contribution of PM10 and PM2.5 sub-category emissions to waste sector total emissions

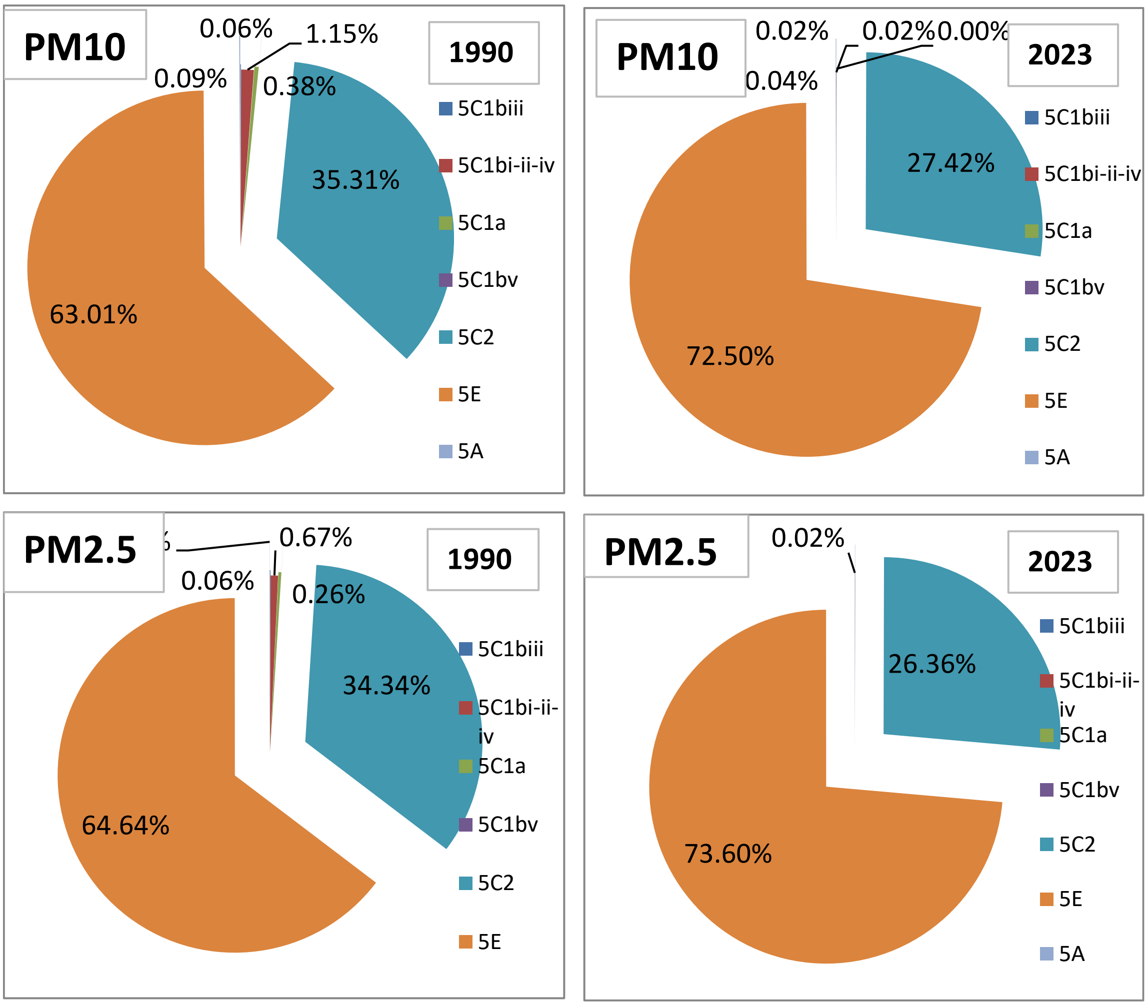


Table 7.15 Time series emissions in the waste sector by category and pollutant

WASTE SECTOR	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
Solid waste disposal (5A)										
NMVOC (Gg)	6.43	7.97	9.06	8.96	8.20	7.39	7.51	7.38	7.32	7.37
NH_3 (Gg)	5.21	6.46	7.35	7.26	6.65	5.99	6.09	5.98	5.93	5.98
PM10 (Gg)	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.002
PM2.5 (Gg)	0.0006	0.0006	0.0006	0.0005	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003
Biological treatment of waste (5B)										
NMVOC (Gg)	0.01	0.03	0.14	0.28	0.36	0.37	0.35	0.35	0.33	0.31
NH_3 (Gg)	0.07	0.20	0.70	0.95	0.41	2.58	3.15	3.21	3.13	3.05
Waste incineration (5C)										
CO (Gg)	61.69	67.73	65.89	89.00	87.99	88.59	86.17	85.13	77.84	80.65
NO_x (Gg)	2.70	2.69	2.27	2.89	2.73	2.65	2.55	2.62	2.40	2.47
NMVOC (Gg)	1.99	1.93	1.01	1.42	0.98	0.47	0.40	0.51	0.45	0.45
SO_x (Gg)	0.55	0.49	0.30	0.36	0.26	0.20	0.14	0.19	0.17	0.17
NH3 (Gg)	0.0012	0.0008	0.0005	0.0002	0.0002	-	-	-	-	-
PM10 (Gg)	1.78	2.04	1.97	2.29	1.80	1.71	1.59	1.61	1.56	1.58
PM2.5 (Gg)	1.66	1.91	1.85	2.15	1.70	1.62	1.51	1.52	1.47	1.50
BC (Gg)	0.80	0.87	0.85	1.15	1.14	1.14	1.11	1.10	1.00	1.04
PAH (t)	1.27	1.23	1.16	1.53	1.32	1.41	1.37	1.36	1.29	1.32
Dioxins (g I-Teq))	103.15	79.52	28.60	9.84	9.63	9.68	9.40	9.31	8.51	8.82
HCB (kg)	12.86	13.97	9.87	8.27	0.49	0.98	0.85	1.07	1.05	1.07
PCB (kg)	5.36	4.62	2.08	1.55	0.57	1.03	0.91	1.14	1.11	1.14
As (t)	0.09	0.09	0.07	0.08	0.06	0.06	0.06	0.06	0.05	0.06
Cd (t)	0.59	0.57	0.46	0.61	0.44	0.48	0.43	0.45	0.41	0.42
Cr (t)	0.66	0.58	0.35	0.41	0.12	0.12	0.10	0.12	0.10	0.11
Cu (t)	0.99	0.86	0.55	0.50	0.13	0.18	0.12	0.17	0.15	0.15
Hg (t)	0.33	0.32	0.23	0.31	0.22	0.11	0.08	0.10	0.09	0.09
Ni (t)	6.79	4.37	2.84	1.06	0.05	0.06	0.05	0.06	0.05	0.05
Pb (t)	5.90	5.53	2.76	4.05	0.26	0.20	0.18	0.19	0.18	0.18
Se (t)	0.04	0.04	0.03	0.04	0.04	0.04	0.05	0.05	0.04	0.04
Zn (t)	5.28	6.32	4.73	6.11	3.78	3.59	3.37	3.37	3.32	3.30
Wastewater (5D)										
NMVOC (Gg)	0.08	0.10	0.10	0.11	0.12	0.11	0.13	0.14	0.14	0.14

WASTE SECTOR	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
NH_3 (Gg)	2.82	3.11	3.59	3.80	3.81	3.58	3.06	3.00	2.93	2.87
Other waste (5E)										
PM2.5 (Gg)	3.04	3.05	3.05	3.13	2.76	3.29	4.09	4.39	4.30	4.17
BC (Gg)	0.56	0.56	0.57	0.58	0.51	0.61	0.76	0.81	0.80	0.77
PCDD/F (g I-Teq)	31.18	31.21	31.28	32.01	28.20	33.56	41.53	44.47	43.63	42.39
Cd (t)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hg (t)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02
Pb (t)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02

7.4 RECALCULATIONS

In the following table the recalculations occurred in the 2025 submission with respect to the last year submission are reported at category level.

Table 7.16 Recalculations in the waste sector by category and pollutant

WASTE SECTOR	1990	1995	2000	2005	2010	2015	2020	2021	2022
Solid waste disposal (5A)									
NMVOC	-	-	-	-	-	-	-0.02%	-0.02%	-0.02%
NH_3	-	-	-	-	-	-	-0.02%	-0.02%	-0.02%
PM10	-	-	-	-	-	-	-	-	-
PM2.5	-	-	-	-	-	-	-	-	-
Biological treatment of waste (5B)									
NMVOC	-	-	-	-	-	-	-	-	-
NH_3	-	-	-	-	-0.4%	-3.3%	-8.5%	-10.2%	-10.6%
Waste incineration (5C)									
CO	-	-	-	22.8%	28.4%	29.2%	29.4%	29.0%	28.4%
NO_x	-	-	-	18.4%	24.0%	25.8%	26.4%	24.8%	22.5%
NMVOC	-	-	-	-	-	-	-	-	-13.8%
SO_x	-	-	-	5.8%	10.0%	13.7%	20.1%	13.5%	2.0%
NH_3	-	-	-	-	-	NA	NA	NA	NA
PM10	-	-	-	15.4%	17.8%	18.5%	18.5%	18.8%	14.5%
PM2.5	-	-	-	15.6%	17.8%	18.6%	18.5%	18.8%	14.6%
BC	-	-	-	22.8%	28.4%	29.2%	29.5%	29.1%	28.4%
PAH	-	-	-	25.8%	34.7%	35.3%	35.0%	34.1%	33.9%

WASTE SECTOR	1990	1995	2000	2005	2010	2015	2020	2021	2022
Dioxins	-	-	-	22.3%	28.1%	29.0%	29.3%	28.8%	28.0%
HCB	-	-	-	-	-	-	-	-	-2.1%
PCB	-	-	-	-	-	-	-	-	-2.1%
As	-	-	-	13.3%	25.8%	23.7%	26.3%	23.7%	21.9%
Cd	-	-	-	21.3%	37.4%	36.4%	39.2%	36.1%	35.3%
Cr	-	-	-	5.0%	25.2%	24.5%	29.8%	24.3%	20.0%
Cu	-	-	-	3.3%	17.0%	12.6%	18.7%	12.8%	5.5%
Hg	-	-	-	6.2%	10.1%	24.6%	36.1%	25.2%	19.2%
Ni	-	-	-	0.9%	30.8%	25.5%	31.1%	24.9%	21.2%
Pb	-	-	-	0.4%	9.0%	12.5%	13.3%	12.4%	6.8%
Se	-	-	-	20.4%	25.4%	24.5%	23.4%	22.8%	22.2%
Zn	-	-	-	2.6%	5.1%	5.5%	5.8%	5.7%	0.1%
Wastewater (5D)									
NMVOC	-	-	-	-	-	-	-	-	0.01%
NH3	-	-	-	-	-	-	-	-	-
Other waste (5E)									
PM2.5	-	-	-	-	-	-	-	-	-
BC	-	-	-	-	-	-	-	-	-
PCDD/F	-	-	-	-	-	-	-	-	-
Cd	-	-	-	-	-	-	-	-	-
Hg	-	-	-	-	-	-	-	-	-
Pb	-	-	-	-	-	-	-	-	-

As regards waste disposed of in landfills, minor recalculations occur for NMVOC and NH_3 because of a fixed error in the model for 2016. Minor recalculations start from 2017 because of the delay time.

AS regards biological treatments, N-NH3 from manure have been revise since 2007 resulting in variations of -0.4% in 2010 and -10.6% in 2022. Data for N contained in livestock manure (sent to digesters) have been updated: for cattle since 2007 and for other poultry since 2012. For cattle, this change comes from updating the percentages of grazing livestock based on the 2020 Census of Agriculture. For other poultry, the change would start from 2010, but the share of poultry manure was started to anaerobic digestion from 2012. This change stems from the update of the average weight of other poultry, made on the basis of the 2020 Census of Agriculture. In addition, based on GSE (Energy Services Manager) data of biomethane production, disaggregated by production source (organic substrate of agricultural origin), the amount of livestock manure sent to anaerobic digestion from 2017-2022 has been updated. This change only affects cattle emissions (as the methodology is set up).

For wastewater, minor recalculations regard the update of landfilled sludge data for the year 2022 as well as the update of the wastewater generation in the leather industry for the year 2022 too.

As concerns incineration, in general recalculations occur in 2022 because of the update of activity data of industrial and clinical waste reported by ISPRA (ISPRA, several years) in December 2024.

As regards emissions from 5C2 open burning of agricultural residues emissions have been recalculated since 2001 because of the implementation of data from a survey concerning the amount of agricultural residues. The identification of larger quantities of cultural residues has led to a significant increase in emissions. The emissions change because residue-to-grain ratios for cereals have been updated based on the internship work of Mounérat Nathan (Internship Mounérat N., 2024), starting in 2001 (the new values have been applied since 2006, and a smooth transition was estimated before). Cereal residue data from Motola *et al* (Motola V. *et al*, 2009) were processed. Based on this change, the coefficients for estimating the removable residue (and consequently also the fixed residue) of cereals since 2001 have been updated. The 2022 rice production figure has been updated.

7.5 PLANNED IMPROVEMENTS

Recently, in the previous submissions, estimates of PM emissions have been included in the inventory for solid waste disposed on landfills. Starting with the last NEC review, Italy is studying the most appropriate way to consider the contribution of inert materials to PM emissions, not only to ensure that the best available data is used but also to integrate the estimation system within the landfill emissions model.

8 OTHER (6A) and memo items

8.1 OTHER (6A)

NH_3 emissions from dog and cat droppings are reported in this category. Emissions have been estimated by applying the tier 1 approach and NH_3 emission factors for cats and dogs from the EMEP/EEA Guidebook (EMEP/EEA, 2023).

The time series of the number of cats has been estimated starting from the data of FEDIAF (European Pet Food Industry Federation) report 2021 and 2022 (FEDIAF, 2022; 2023). The number of cats per household has been calculated for the years 2021-2022 as the number of cats divided by the number of households (source ISTAT- http://dati.istat.it/). The number of cats for the period 1990-2020 has been estimated as the product of the number of households of a certain year (source ISTAT/EUROSTAT) and the average percentage 2021-2022 number of cats per household. The same value was used for 2023 as for 2022.

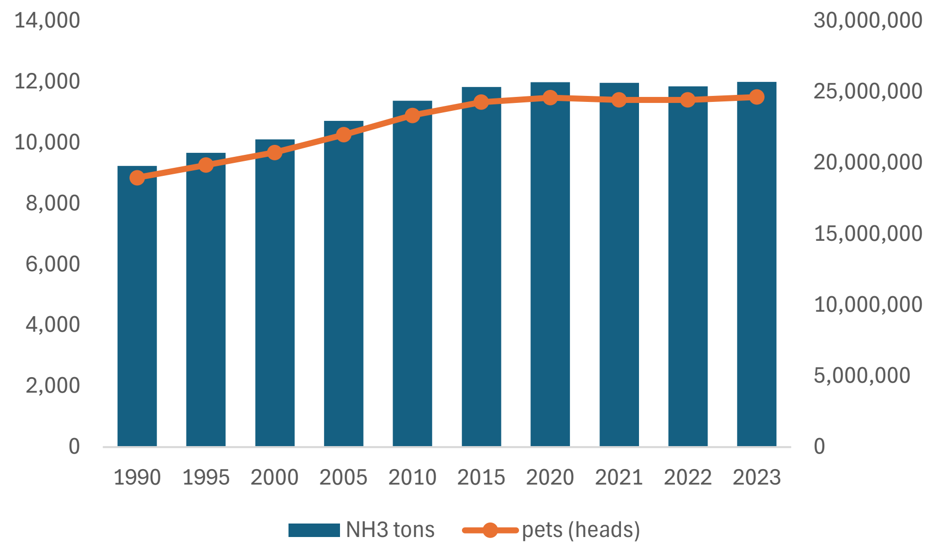
The time series of the number of dogs has been estimated starting from the data of the Canine Registry managed by the Ministry of Health, collecting data of regional registries (*Anagrafi territorali* - https://www.salute.gov.it/anagcaninapublic_new/AdapterHTTP). The number of dogs per household for the year 2022 has been estimated as the number of dogs divided by the number of households. The number of dogs for the period 1990-2021 has been estimated as the product of number of households of a certain year (source ISTAT/EUROSTAT) and the number of dogs per household for the year 2022. From 2022 the data are available online.

8.1.1 TIME SERIES AND KEY CATEGORIES

In 2023, key category level was identified for 6A NH_3 emissions and for trend analysis; on the other hand, in 1990 they are not.

In Figure 8.1 NH_3 emissions trend are reported.

Figure 8.1 NH3 emissions from pets (dogs and cats)



8.1.2 QA/QC AND VERIFICATIONS

Other data sources were consulted to verify activity data on dogs bred by Italian families, such as FEDIAF, ENCI (*Ente Nazionale della Cinofilia Italiana* – National board of italian dog breeding) and FCI (Federation Cynologique Internationale).

8.1.3 RECALCULATIONS

No recalculation occurred.

8.1.4 PLANNED IMPROVEMENTS

No improvement is planned.

8.2 MEMO ITEMS – WILDFIRES

According to Guidelines for Reporting Emissions and Projections Data under the Convention on Long-range Transboundary Air Pollution natural emissions from forest fires, volcanoes, etc., shall not be included in national totals.

8.2.1 FOREST FIRES

Air pollutants and non-CO_2 GHG emissions from forest fires are estimated on the basis of a bookkeeping model, called For-fires. It is described in annex 13 of NID 2025 (ISPRA, 2025).

For-fires model is based on the on the equation 2.27 of the 2006 IPCC Guidelines (vol. 4, ch. 2):

L_fire=A×M_B×C_(f)×G_ef×10^(-3)

where

Lfire amount of air pollutants or greenhouse gas emissions released from fire;

A burned area (hectares);

MB mass of fuel available for combustion (t ha-1);

Cf combustion factor (dimensionless);

Gef emission factors (g kg-1 dry matter burnt).

The burned area (A) for each fire event is recorded annually by the regional forestry corps (in four Italian autonomous regions) and by the Carabinieri Force (for all other regions).

For each fire event, the mass of fuel available (MB) is derived from the 2nd and 3rd National Forest Inventory (NFI 2005 and NFI 2015) considering the regional distribution of wildfires and forest typology affected, when known. The MB includes both biomass and necromass (dead wood and litter) carbon pools.

The combustion factor (Cf) term is the most parameter, representing the fraction of pre-disturbance mass that is combusted during the fire event. Its estimation follows the approach developed by Bovio (2007) and the data collected, annually, for each fire event, by Carabinieri Force[7]. This method assesses forest fire damage in Italy by considering two key elements: the burned forest typology, and fire intensity (assessed through the scorch height).

The emission factors (Gef) applied to the calculation are derived from the following sources:

- 2006 IPCC (IPCC, 2006), Table 2.5 for extra tropical forest category, and
- EMEP/EEA Guidebook 2023 (EMEP/EEA, 2023), specifically in:
    - chapter 11.B, Table 3-5 focusing on temperate forest category, and
    - chapter 5.C.2, Table 3-1 and 3-2.

Emission factors are summarized in Table 8.1

[7] the Armed Forces and Police Authority where the State Forestry Service is embedded, following the legislative decree 19/08/2016, n. 177

Table 8.1 CO, CH_4, NO_x, N_2O, PM10, PM2.5, Dioxin and PAH emission factors

Pollutant/GHG	*emission factor*	*unit*	*reference*
CO	107	*g X/kg dry matter burned*	IPCC 2006 (Table 2.5)
CH_4	4.7	*g X/kg dry matter burned*	IPCC 2006 (Table 2.5)
NO_X	3.0	*g X/kg dry matter burned*	IPCC 2006 (Table 2.5)
N_2O	0.26	*g X/kg dry matter burned*	IPCC 2006 (Table 2.5)
PM10	11	*g X/kg dry matter burned*	EMEP/EEA 2023 (Table 3-5)
PM2.5	9	*g X/kg dry matter burned*	EMEP/EEA 2023 (Table 3-5)
Dioxin	10	*µ I-TEQ/Mg dry matter*	EMEP/EEA 2023 (Table 3-1)
PAH	14.75	*g/Mg dry matter*	EMEP/EEA 2023 (Table 3-2)

NMVOC, NH_3, SO_2 and BC emissions are estimated based on emission ratios provided in the EMEP/EEA Guidebook 2023 (EMEP/EEA, 2023), specifically in chapter 11.B, Table 3-3 and Table 3-5, as summarized in Table 8.2.

Table 8.2 NMVOC, NH_3, SO2 and BC emission ratios

pollutant	*emission ratios*	*unit*	*reference*
NMVOC	21	*g X/kg C emitted as CO_2*	EMEP/EEA 2023 (Table 3-3)
NH_3	1.8	*g X/kg C emitted as CO_2*	EMEP/EEA 2023 (Table 3-3)
SO_2	1.6	*g X/kg C emitted as CO_2*	EMEP/EEA 2023 (Table 3-3)
BC	9	*% of $PM_{2.5}$*	EMEP/EEA 2023 (Table 3-5)

8.2.2 OTHER LAND USE FIRES

Other land uses affected by fires are cropland, grassland and settlements.

Fire statistics for these land use categories are collected from the Carabinieri Force, which has been responsible for burned area data collection since the legislative decree 19/08/2016, n. 177, following the incorporation of the State Forestry Service into the Armed Forces and Police Authority.

To estimate emissions from wildfires occurring in cropland and grassland categories the same IPCC equation described in the previous section is applied. In this case:

- the mass of fuel available for combustion (MB) is derived from table 2.4 of the 2006 IPCC Guidelines (vol. 4, chapter 2),
- a combustion factor (Cf) of 1 is assumed as a conservative approach, meaning the total fuel consumption is considered,
- the same emission factors and ratios used in the For-fires model are applied (see Table 8.1 and Table 8.2).

Although fires affecting settlements are recorded, no emissions are estimated, as they are assumed to be insignificant.

Table 8.3 provides a summary of emissions from wildfires across the three main affected land use categories.

Table 8.3 Emissions from wildfires. Values are expressed in kt where not explicitly indicated (Dioxin and PAH)

Fires	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
					Forest land					
CO	276.10	56.26	139.15	57.19	48.63	66.89	97.86	261.35	173.73	98.36
NMVOC	23.19	4.72	11.69	4.80	4.08	5.62	8.22	21.95	14.59	8.26
NO_x	7.74	1.58	3.90	1.60	1.36	1.88	2.74	7.33	4.87	2.76
NH_3	1.99	0.40	1.00	0.41	0.35	0.48	0.70	1.88	1.25	0.71
SO_2	1.77	0.36	0.89	0.37	0.31	0.43	0.63	1.67	1.11	0.63
PM10	28.38	5.78	14.30	5.88	5.00	6.88	10.06	26.87	17.86	10.11
PM2.5	23.22	4.73	11.70	4.81	4.09	5.63	8.23	21.98	14.61	8.27
BC	2.09	0.43	1.05	0.43	0.37	0.51	0.74	1.98	1.32	0.74
Dioxin (g TEQ)	25.80	5.26	13.00	5.34	4.54	6.25	9.15	24.42	16.24	9.19
PAH (kg)	38,060	7,755	19,2	7,884	6,703	9,220	13,490	36,027	23,949	13,559
					Cropland					
CO	2.47	0.71	1.44	0.67	0.53	1.09	0.91	2.67	1.81	0.83
NMVOC	0.23	0.07	0.13	0.06	0.05	0.10	0.08	0.25	0.17	0.08
NO_x	0.07	0.02	0.04	0.02	0.01	0.03	0.03	0.07	0.05	0.02
NH_3	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.01
SO_2	0.02	0.01	0.01	0.00	0.00	0.01	0.01	0.02	0.01	0.01
PM10	0.25	0.07	0.15	0.07	0.05	0.11	0.09	0.27	0.19	0.08
PM2.5	0.21	0.06	0.12	0.06	0.04	0.09	0.08	0.22	0.15	0.07
BC	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.02	0.01	0.01
Dioxin (g TEQ)	0.23	0.07	0.13	0.06	0.05	0.10	0.09	0.25	0.17	0.08
PAH (kg)	340.83	98.09	198.41	91.81	73.19	150.85	125.40	367.67	250.17	113.95
					Grassland					
CO	312.43	82.22	182.87	78.87	108.58	44.80	43.46	139.08	129.54	58.01
NMVOC	28.82	7.58	16.87	7.28	10.02	4.13	4.01	12.83	11.95	5.35
NO_x	8.76	2.31	5.13	2.21	3.04	1.26	1.22	3.90	3.63	1.63
NH_3	2.47	0.65	1.45	0.62	0.86	0.35	0.34	1.10	1.02	0.46
SO_2	2.20	0.58	1.29	0.55	0.76	0.31	0.31	0.98	0.91	0.41
PM10	32.12	8.45	18.80	8.11	11.16	4.61	4.47	14.30	13.32	5.96
PM2.5	26.28	6.92	15.38	6.63	9.13	3.77	3.66	11.70	10.90	4.88
BC	2.37	0.62	1.38	0.60	0.82	0.34	0.33	1.05	0.98	0.44
Dioxin (g TEQ)	29.20	7.68	17.09	7.37	10.15	4.19	4.06	13.00	12.11	5.42

Fires	1990	1995	2000	2005	2010	2015	2020	2021	2022	2023
PAH (kg)	43,069	11,334	25,209	10,872	14,968	6,175	5,991	19,172	17,857	7,996
Total emissions from fires										
CO	591	139.19	323.46	136.73	157.74	112.78	142.23	403.1	305.08	157.2
NMVOC	52.24	12.37	28.69	12.14	14.15	9.85	12.31	35.03	26.71	13.69
NO_x	16.57	3.91	9.07	3.83	4.41	3.17	3.99	11.3	8.55	4.41
NH_3	4.48	1.06	2.46	1.04	1.21	0.84	1.05	3	2.28	1.18
SO_2	3.99	0.95	2.19	0.92	1.07	0.75	0.95	2.67	2.03	1.05
PM10	60.75	14.3	33.25	14.06	16.21	11.6	14.62	41.44	31.37	16.15
PM2.5	49.71	11.71	27.2	11.5	13.26	9.49	11.97	33.9	25.66	13.22
BC	4.48	1.06	2.44	1.04	1.19	0.86	1.08	3.05	2.31	1.19
Dioxin (g TEQ)	55.23	13.01	30.22	12.77	14.74	10.54	13.3	37.67	28.52	14.69
PAH (kg)	81,470	19,187	44,589	18,848	21,744	15,547	19,606	55,567	42,056	21,669

9 RECALCULATIONS AND IMPROVEMENTS

9.1 RECALCULATIONS

To meet the requirements of transparency, consistency, comparability, completeness and accuracy of the inventory, the entire time series is checked and revised every year during the annual compilation of the inventory. Measures to guarantee and improve these qualifications are undertaken and recalculations should be considered as a contribution to the overall improvement of the inventory.

Recalculations are elaborated on account of changes in the methodologies used to carry out emission estimates, changes due to different allocation of emissions as compared to previous submissions, changes due to error corrections and in consideration of new available information.

The complete NFR files from 1990 to 2023 have been submitted. The percentage difference between the time series reported in the 2024 submission and the series reported this year (2025 submission) are shown in Table 9.1 by pollutant. Further information is available in the relevant chapter.

Improvements in the calculation of emission estimates have led to a recalculation of the entire time series of the national inventory. Considering the total emissions, the emission levels for the year 2022 show a decrease for some pollutants and an increase for others; in particular, a significant decrease has been observed for NO_X emissions, equal to -4.8%, but on the other side a significant increase of emissions has been observed in 2022 for NMVOC (3.1%) because of recalculations in the solvent use sector.

For 1A1, no recalculations occur.

For 1A2, in general, recalculations in 2022 are due to the update of activity data reported in the National Energy Balance or in production activity data. Recalculations greater than ±1% occurred in 2022 for NO_X (-7.8%) and NH_3 (-14.1%) because of the update of the relevant emission factors from cement production; for PM10 (+1.0%) because of the update of lime production activity data; for Hg (-1.1%) and Pb (+2.6%) because of the update of the emission factor from lead and zinc production. As regards lead and zinc production in Italy there is a sole integrated plant for the primary productions and the consultation of environmental permits and data declared in the EPRTR framework led to a gap filling operation and therefore to minor recalculations for the years 2014-2018 and 2020-2022.

In 2025 submission the historical series has been revised mainly as a result of the upgrade of COPERT model version used (from version 5.6.1 in last submission to 5.7.3 in submission 2024 (EMISIA, 2024)): Emission factors of Euro 6 CNG passenger cars, Euro VI diesel buses, Euro VI diesel hybrid buses, non-exhaust emission factors have been updated. As regards the software, revisions relate: the removal of CO_2 correction tool, capability of alternative HDVs classification based on REG EU 2017/2400, improved labels of forms and headers. Furthermore various bugs have been corrected.

For 1.A.3.dii national navigation, recalculations, respect to the previous submission occurred. ISTAT reviewed the number of ships arriving in Italian ports in 2022; therefore, emissions have been updated accordingly.

Some recalculations affected 1A4 category in this submission due to the update of incineration with energy recovery. Major differences have been found in 2022 because of the update of activity data resulting in -16% for HCB and -10% for PCB emissions, for other pollutants recalculations are less than ±0.5%. Minor recalculations have occurred throughout the time series because of the update of historical data of a single plant in the years 2002 and 2006-2010. More, the reconstruction of old info about another plant led to recalculations on dioxins emission in the years 1995-200, 2002, 2005-2010 with differences from -3% in 1995 to -43% in 2007, year for which a bug was fixed.

As regards 1B subsector, recalculations occurred for NMVOC emissions in 2022 from liquid fuel distribution because of the update of activity data resulting in a variation equal to +1.9%.

In the industrial processes sector, NFR code 2, recalculations occur:

- for emissions from category 2.A.5.b and 2.H.2 in 2022 due to the update of activity data;
- for 2B in 2021 and 2022 due to the update of activity data;

- for NMVOC emissions from lubricants use because of the update of the activity data.

As regards the use of solvent recalculations occurred for different categories during this year's submission. In paint application, a revision of activity data and emission factor for 2019 in the manufacture of automobile occurred. Emission factors were revised also for construction and buildings and domestic use for 2021 and 2022. In response to the review process, and the use of the figures in the EMEP /EEA Guidebook 2023, the emission factor for metal degreasing was revised from 2000. In chemical product processing and manufacturing, a recalculation occurred on account of a change in EFs for leather tanning for 2021 and activity data from 2008 due to information available from the industrial association reports. Major recalculations affected the domestic solvent use category, where following the review recommendations, the use of hand sanitizers in Italy was further examined and a recalculation occurred both in activity data and emission factors, based on ethanol data provided by a study by ESIG and TNO.

Recalculations were implemented for the agricultural emission inventory. Major recalculations of NH_3 emissions are due to: the update of percentages of dairy cattle and non-dairy cattle on pasture; the update of EFs from livestock housing and storage for different categories, NH_3 emissions from storage have been corrected by removing from the overall estimate of NH_3 from storage only the portion of NH_3 from storage of digestate in open tank, The numbers of laying hens and broilers from 2020 and turkeys in the years 2017-2022 were updated, an update of the combusted fraction of rice residues since 1990 has been carried out, which involves recalculation of NH_3 emissions from crop residues. Many of these variations also justify the NOx recalculations. The update of poultry activity data is responsible for PM recalculations too. The breakdown of NMVOC emissions between liquid and solid management system since 2006 was updated based on the variation over the years between liquid and solid system of laying hens (previously, a fixed figure had been left since 2006).
As regards field burning, the emissions change because residue-to-grain ratios for cereals have been updated based on the internship work of Mounérat Nathan (Internship Mounérat N., 2024), starting in 2001 (the new values have been applied since 2006, and a smooth transition was estimated before). Cereal residue data from Motola *et al* (Motola V. *et al*, 2009) were processed. Based on this change, coefficients for estimating the removable residue (and consequently also the fixed residue) of cereals have been updated since 2001. The 2022 rice production figure has been updated. Based on these changes, there is a recalculation of emissions from stubble burning of NH_3, NMVOC, NOx, PM, BC, CO, PAH, HM, Dioxins. More info in the relevant chapter.

As regards waste disposed of in landfills, minor recalculations occur for NMVOC and NH_3 because of a fixed error in the model for 2016. Minor recalculations start from 2017 because of the delay time. As regards biological treatments, N-NH3 from manure have been revise since 2007. Changes made in the agricultural sector are reflected on the waste sector. For wastewater, minor recalculations regard the update of landfilled sludge data for the year 2022 as well as the update of the wastewater generation in the leather industry for the year 2022 too. As concerns incineration, in general recalculations occur in 2022 because of the update of activity data of industrial and clinical waste reported by ISPRA (ISPRA, several years) in December 2024. As regards emissions from 5C2 open burning of agricultural residues emissions have been recalculated since 2001 because of the implementation of data from a survey concerning the amount of agricultural residues.

Table 9.1 Recalculation between 2024 and 2025 submissions (%)

	SO_X	NO_X	NH_3	NMVOC	CO	PM10	PM2.5	BC	Pb	Hg	Cd	DIOX	PAH	HCB	PCB
	%														
1990	-	0.01	-0.00	1.85	-	0.05	0.01	-4.32	-	-	-	-	-	-	-
1991	-	0.01	0.00	1.79	-	0.04	0.01	-4.64	-	-	-	-	-	-	-

	SOx	NOx	NH3	NMVOC	CO	PM10	PM2.5	BC	Pb	Hg	Cd	DIOX	PAH	HCB	PCB
								%							
1992	-	0.01	0.00	1.73	-	0.05	0.01	-3.99	-	-	-	-	-	-	-
1993	-	0.01	0.00	1.73	-	0.05	0.01	-4.28	-	-	-	-	-	-	-
1994	-	0.01	0.03	1.88	-	0.05	0.01	-3.65	-	-	-	-0.00	-	-	-
1995	-	0.01	0.03	1.90	-	0.05	0.01	-4.07	-	-	-	-0.51	-	-	-
1996	-	0.01	0.03	1.95	-	0.05	0.01	-4.00	-	-	-	-0.56	-	-	-
1997	-	0.01	0.03	2.08	-	0.06	0.01	-3.47	-	-	-	-0.56	-	-	-
1998	-	0.01	0.02	2.60	-	0.06	0.01	-3.72	-	-	-	-0.58	-	-	-
1999	-	0.01	0.03	2.79	-	0.06	0.01	-3.47	-	-	-	-1.10	-	-	-
2000	-	0.01	0.02	2.82	-	0.07	0.01	-3.65	-	-	-	-1.06	-	-	-
2001	0.00	0.01	0.04	3.07	0.08	0.10	0.07	-3.55	0.00	0.03	0.25	0.09	0.13	-	-
2002	0.01	0.03	0.05	3.32	0.21	0.14	0.16	-3.77	0.18	0.19	0.92	-0.87	0.40	0.06	0.12
2003	0.00	0.03	0.06	3.43	0.29	0.19	0.19	-3.49	0.00	0.09	0.94	0.29	0.38	-	-
2004	0.01	0.05	0.09	3.78	0.55	0.27	0.33	-3.98	0.01	0.17	1.60	0.51	0.82	-	-
2005	0.01	0.84	0.17	3.94	0.71	-0.02	-0.11	-5.10	-0.10	0.20	1.61	-0.20	0.61	-0.00	-0.00
2006	0.01	-0.26	0.47	4.19	0.90	0.21	0.23	-4.07	-0.05	0.22	2.02	0.29	0.65	-0.00	-0.00
2007	0.01	-0.51	0.51	4.31	0.88	0.11	0.11	-4.37	-0.10	0.24	2.00	-0.37	0.50	-0.01	-0.00
2008	0.02	-0.67	0.46	4.35	0.89	0.11	0.09	-4.47	-0.14	0.30	2.65	0.46	0.52	-0.02	-0.00
2009	0.01	-0.79	0.43	4.47	0.92	0.01	0.02	-4.54	-0.22	0.33	2.69	0.52	0.46	-0.14	-0.03
2010	0.00	0.96	0.48	4.91	1.00	-0.08	-0.12	-5.58	-0.45	0.32	2.74	0.33	0.42	-0.04	-0.01
2011	0.02	-1.23	0.56	5.43	0.96	-0.07	-0.09	-4.83	-0.32	0.31	2.83	0.54	0.58	-0.00	-0.00
2012	0.03	-1.34	0.85	5.51	0.87	-0.04	-0.04	-4.01	-0.35	0.30	3.21	0.54	0.49	-0.00	-0.00
2013	0.03	-1.54	1.05	5.88	0.97	-0.26	-0.09	-4.11	-0.41	0.35	3.41	0.50	0.49	-0.00	-0.00
2014	0.03	-2.20	1.32	6.23	0.89	-0.46	-0.25	-4.18	-0.81	0.33	3.30	0.46	0.49	-0.00	-0.00
2015	0.04	-2.44	1.21	6.32	0.90	-0.45	-0.21	-3.93	-0.87	0.40	3.45	0.51	0.51	-0.00	-0.00
2016	0.04	-3.00	0.94	4.46	1.00	-0.47	-0.18	-3.56	-0.82	0.49	4.03	0.63	0.62	-0.00	-0.00
2017	0.04	-2.15	0.43	3.63	0.91	-0.33	-0.06	-2.90	-0.70	0.39	3.39	0.54	0.50	-0.00	-0.00
2018	0.04	-2.22	-0.32	3.84	1.03	-0.23	0.07	-1.39	-0.75	0.40	3.38	0.72	0.56	0.00	0.00
2019	0.04	-2.43	-0.91	4.21	0.96	-0.56	-0.34	-4.09	-0.55	0.42	3.40	0.34	0.56	-0.01	-0.00
2020	0.05	-1.87	-1.36	9.56	1.10	-0.38	-0.02	-1.25	-0.44	0.48	3.92	0.68	0.68	-0.00	-0.00
2021	0.06	-1.99	-1.25	6.39	1.01	0.22	0.08	-1.26	-0.51	0.43	3.37	0.59	0.56	-0.00	-0.00
2022	-1.77	-4.79	-0.93	3.09	1.05	-2.32	-1.00	-4.23	1.28	0.18	2.98	0.26	0.46	-2.44	-0.29

9.2 PLANNED IMPROVEMENTS

Specific improvements are specified in the QA/QC plan (ISPRA, 2025[b]); they can be summarized as follows.

For the energy and industrial processes sectors, a major progress regards the harmonization of information collected in the framework of different obligations, Large Combustion Plant, E-PRTR and Emissions Trading, thus highlighting the main discrepancies in data and detecting potential errors, the use of data and country specific emission factors collected in national research involving road transport and biomass consumption in residential. Currently, a review process of the national energy balance is underway with the national energy experts. In this framework, it is planned the integration, where possible, of fuel consumption data reported under the ETS in the National Energy Balance. As regards 1A4 sectors, the updating of average emission factors will continue in future submissions on the basis of the surveys on wood consumption and combustion technologies planned by ISTAT on fuel consumptions as well as from the results of an emission factor measurements campaign realized in Italy. An in depth analysis of emission factors resulting from this experimental studies and their comparison with the values suggested by the last version of the EMEP/EEA Guidebook (EMEP/EEA, 2023) will be carried out and emission factors will be updated as needed.

For the agriculture and waste sectors, improvements will be related to the availability of new information, on emission factors, activity data as well as parameters necessary to carry out the estimates; specifically, a study on the best available technologies used in agriculture practices, the elaboration of data from the last farm structure survey and the agricultural census, and availability of information from the exceeding biogas flared at wastewater treatment plants are under investigation. More, in the coming years, based on regional data on livestock manure management techniques, particularly from the Po River Basin area, a review of statistical data provided by ISTAT and collected as part of the Census and triennial Farm Structure Surveys will be undertaken.

The EMEP/EEA Guidebook 2019 chapters (EMEP/EEA, 2019) has continued to be considered but the 2023 version started to be used. The update of emission factors will be assessed and applied in the next year submission of the inventory with a focus to PAH estimates in order to improve the completeness, e.g. for PAH compounds, accuracy and reduce the uncertainty.

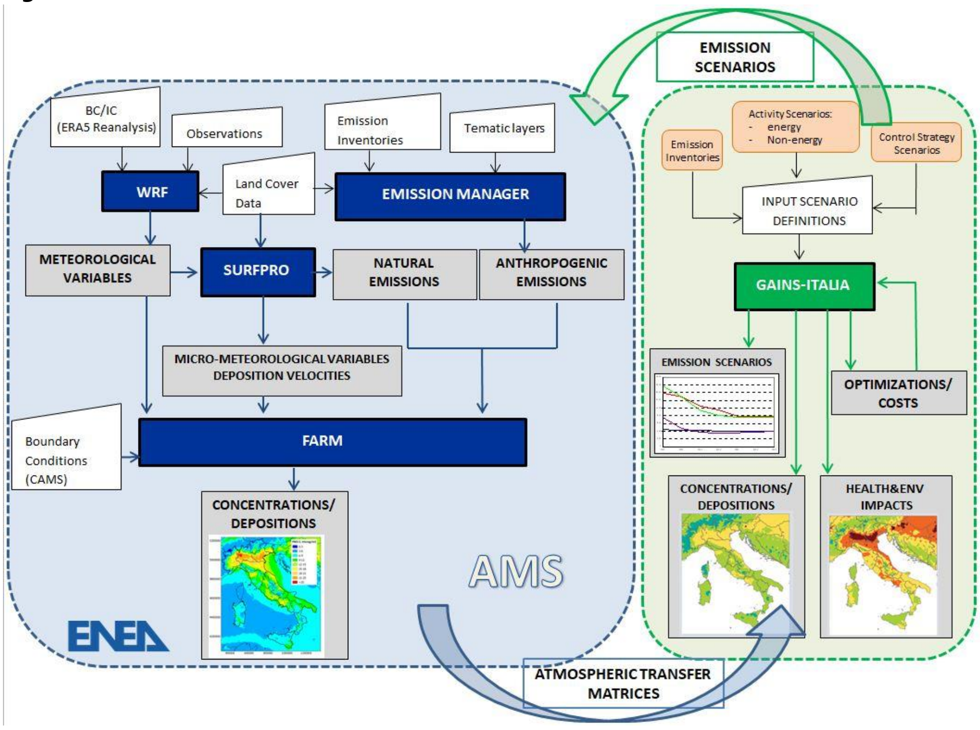
The comparison between local inventories and national inventory and the meetings and exchange of information with local environmental agencies will continue.

Further analyses will concern the collection of statistical data and information to estimate uncertainty in specific sectors.

10 PROJECTIONS

At national level, the Legislative Decree n. 155 of 2010 (D.Lgs. 2010), that implements the European Directive on air quality, 2008/50/EC (EC, 2008), and the Legislative Decree n. 81 of 2018 (D.Lgs. 2018), that implements the Directive (EU) 2016/2284, provide that ISPRA develops the energy scenario and the scenario of national production activities while ENEA, based on these scenarios, calculates the emission projections using the methodology developed for these purposes at European level. In this framework, ENEA has elaborated the new national baseline emission scenario using the GAINS-Italy model. GAINS-Italy is part of the MINNI model, an Integrated Modelling System that links atmospheric science with the economics of emission abatement measures and policy analysis and consists of several interdependent and interconnected components: the national AMS (Atmospheric Modeling System, Mircea et al., 2014; D'Elia et al., 2021) and the national GAINS-Italy (Piersanti et al., 2021; D'Elia et al., 2009). They interact in a feedback system through ATMs (Atmospheric Transfer Matrices) and RAIL (RAINS-Atmospheric Inventory link). The GAINS-Italy model (Figure 10.1) explores cost-effective multi-pollutant emission control strategies (Ciucci et al., 2016) that meet environmental objectives on air quality impacts (on human health and ecosystems) and greenhouse gases. The current legislation (CLE) scenario represents the 'baseline' and reflects all policies legally in force, both those affecting activity levels (such as energy and agriculture policies), as well as pollution control policies for the period 1990-2050. The GAINS-Italy model elaborates emission scenarios for air pollutants and greenhouse gases on 5-year time intervals, starting from 1990 to 2050, and evaluates cost-effective multi-pollutant emission control strategies to reach environmental objectives on air quality impacts. Moreover, GAINS-Italy performs fast-response calculations of regional background concentrations of PM2.5 and NO2 in consequence of hypothesized emission reductions on the Italian territory. This last feature is enhanced by the Atmospheric Transfer Matrices (ATMs), simplified (quasi-linear) relations between total regional emissions and concentrations, calibrated through a set of national Atmospheric Modelling System simulations, based on controlled pollutant emission reductions (Briganti et al., 2011). The development of an emission scenario with the GAINS-Italy model requires the definition of anthropogenic activity levels, both energy and non-energy, and of a control strategy with a 5-year interval for the period 1990-2050 in the format required by the model. Starting from these information, GAINS-Italy produces alternative future emission and air quality scenarios and abatement costs at a 5-year interval starting from 1990 to 2050. For the preparation of national emission scenarios, an acceptable harmonization, at a given base year, between the national emission inventory and the GAINS-Italy emissions (D'Elia and Peschi, 2013) has been carried out. More details about the procedure to build an emission scenario could be found in D'Elia and Peschi, 2016.

Figure 10.1 The scheme of the MINNI national model.



The present chapter is based on the National Energy and Climate Plan presented in 2024, as well as the National Air Pollution Control Programme submitted in 2021. Emissions for 2045 and 2050, although being calculated with the same methodology and modelling suite as previous years, are to be interpreted as the inertial effects of the continued implementation of PaMs defined in the NECP (cfr. paragraph 1.2, 3.1 and 3.2 of the NECP) with the year 2040 as time horizon.

The base year for the projections is 2023, the projected years are from 2025 to 2050 with a single year pace up to 2030 and a 5-year pace from 2030 to 2050.

The "With Measures" (WM) scenario considers the policies and measures implemented before December 31st, 2022, unless otherwise specified.

The "With Additional Measures" (WAM) scenario, calculated with the same methodology as the WM scenario, considers all the Policies and Measures included in the NECP that were not yet implemented before 2022.

10.1 MAIN ASSUMPTIONS

Activity data used for pollutants projections are the same used for GHG emission projections submitted under the UNFCCC and its Paris agreement and, in that context, the Enhanced Transparency Framework (ETF) system is an essential tool for ensuring transparency and accuracy.

The scenarios for energy and transport sectors have been calculated with the partial equilibrium model TIMES (The Integrated MARKAL-EFOM1 System / EFOM Energy Flow Optimization Model), a model generator for local, national or multi regional economies finalized to the analysis of whole energy systems (electricity generation and consumption, heat distribution, transports, industries, civil, etc.). The model belongs to the family of MARKAL (Market Allocation, http://www.iea-etsap.org/web/Markal.asp) models, the so-called "3e models" (energy, economy, environment), and was developed by the International Energy Agency (IEA) under the program Energy Technology Systems Analysis Program (ETSAP). This model is recognized by the International Panel on Climate Change (IPCC). The energy system thus simulated is composed by several different sectors and subsectors (e.g., electricity production, industrial activities, residential buildings, etc.), each one consisting of a set of technologies connected by input-output linear relationships. Inputs and outputs can be energy carriers, materials, emissions, or requests for services. TIMES is a bottom-up, demand-driven model in which each technology is identified by technical and economic parameters and the production of a good is conditioned to the effective demand by end-users. The structure of energy scenarios is defined by variables and equations determined by input data constituting the regional database. The database contains qualitative and quantitative data describing the interaction between different components of the energy system. TIMES identifies the optimal solution to provide energy services at the lowest cost, producing simultaneously investments in new technologies or using more intensively the available technologies in each region defined by the user. For example, an increase in electricity demand for residential use can be satisfied with a more intensive use of available power plants or through the installation of new power plants. Model choices are based on the analysis of technological characteristics of available alternatives, the cost of energy supply and environmental criteria and bounds. Activities for non-energy sources have been calculated with a family of spreadsheet models. The expected evolution of GDP and sectoral value added, demographic trends, as well as projections of international fossil fuel prices and CO_2 emission quotas on the ETS market are of particular importance for GHG emission scenarios. The parameters used for this scenario are those provided by the EU Commission for Italy in March 2024, complemented where necessary by the details provided by the European Commission during 2021 as part of the update of the European Reference Scenario. The Table 10.1 below shows assumptions for the evolution of population and GDP between 2022 and 2040: in future years, tertiary sector is expected to continue growing at higher rate than industry, further increasing its role in the Italian economy.

Table 10.1 Main macroeconomic and demographic parameters

			2023	2025	2030	2035	2040	2045	2050
GDP		% growth rate in the year	0.70%	1.20%	0.60%	0.80%	1.40%	1.40%	1.40%
Population		Millions	58.997	58.925	58.761	58.645	58.497	58.128	57.432
		Millions of households	26.207	25.294	25.347	25.364	25.380	25.396	25.358
Sectoral GVA	Agriculture	5 years avg annual rate (%)	-	2.20%	0.40%	-0.10%	0.00%	0.30%	0.30%
	Construction	5 years avg annual rate (%)	-	2.9%	0.79%	0.04%	0.24%	0.94%	1.08%
	Services	5 years avg annual rate (%)	-	3.3%	0.8%	0.7%	1.3%	1.5%	1.5%
	Industry	5 years avg annual rate (%)	-	3.76%	0.53%	0.34%	0.71%	1.01%	0.97%

Source: EU Commission, ISTAT and further elaboration by ISPRA

Table 10.1 also shows data on population and households. Despite the significant population growth from 2005 to 2015, with an annual average rate of 0.49%, a decline has been observed from 2015 to 2020 with an annual rate of -0.19%. The declining trend is expected to continue all through the time series. The number of households is used to estimate the surface area to be heated and cooled in residential buildings. Table 10.2 shows the energy and carbon ETS international prices according to the recommended projections by the European Commission. Energy prices show a strong decrease after 2022 peaks with slightly different trends in the future years for all the commodities. The increase in carbon price is quite significant if compared to 2020 (+210% from 2020 to 2022) and no reduction is expected in the future.

Table 10.2 International Energy prices and carbon prices in the existing ETS1

		2020	2022	2025	2030	2035	2040	2045	2050
Oil	€2023/GJ	7.6	16.7	12.4	13.9	15.4	15.8	17.2	19.7
Natural gas	€2023/GJ	3.7	35.1	9.4	9.0	8.2	10.1	9.9	9.6
Coal	€2023/GJ	1.9	10.9	4.1	4.0	3.8	3.8	4.0	4.0
Carbon price ETS1	€2023/tCO_2	29	90	95	95	100	100	160	190
Carbon price ETS2*	€2023/tCO_2	-	-	-	55	58	58	93	110

**Only used in the WAM scenario*

Source: EU Commission and further elaboration by ISPRA

The WAM scenario also introduces what is known as ETS2, the new system that from 2027 will cover CO_2 emissions from combustion in road transport, buildings and the energy and manufacturing industries that are not covered by the current ETS1. For the years after 2030, in the absence of more robust assumptions, the price was assumed to grow at a similar rate to the ETS1 allowance price.

Table 10.3 Projected GVA average annual rate (%) for industrial sectors

Industrial sector	20-25	25-30	30-35	35-40	40-45	45-50
Iron and steel	8.1%	0.4%	-0.1%	0.0%	0.3%	0.1%
Non ferrous metals	8.3%	0.4%	-0.1%	0.0%	0.2%	0.0%
Chemicals	*2.9%*	*0.6%*	*0.0%*	*0.2%*	*0.8%*	*0.8%*
Non metallic minerals	*4.4%*	*0.7%*	*0.0%*	*0.2%*	*0.7%*	*0.7%*
Pulp, paper and printing	*3.7%*	*0.5%*	*0.0%*	*0.1%*	*0.7%*	*0.8%*
Food, drink and tobacco	3.2%	0.7%	0.0%	0.2%	0.8%	0.9%

Industrial sector	20-25	25-30	30-35	35-40	40-45	45-50
Textiles	4.6%	0.1%	-0.2%	-0.2%	-0.2%	-0.4%
Engineering	3.7%	0.6%	0.8%	1.4%	1.5%	1.4%
Other industries	3.5%	0.5%	0.0%	0.1%	0.7%	0.6%

Source: elaboration by ISPRA on EU commission

For some industrial productions more detailed analyses have been made and physical production of materials have been projected in future years, as reported in Table 10.4.

Table 10.4 Projected physical production (Mt) for selected industrial sectors

	2023	2025	2030	2035	2040	2045	2050
Iron and steel	21.1	27.8	28.3	28.2	28.1	28.5	28.7
Non ferrous metals		1.3	1.3	1.3	1.3	1.3	1.3
Cement and derived products	18.8	19.9	20.5	20.6	20.9	21.9	23.2
Glass	6.1	6.3	6.6	6.6	6.6	6.9	7.1
Paper	7.5	9.2	9.4	9.5	9.5	9.8	10.2

Source: elaboration by ISPRA

Table 10.5 shows data of transport demand for passengers, freight, domestic navigation, and air traffic. The expected activity scenario for transport shows a sharp decline in 2020 due to the mentioned lockdown. After 2020 projections show a steady growth up to 2050. The transport demand decreases up to 2020 compared to 2015 with an annual rate of -7.9% for passengers while show a weak growth of 0.24% for goods. After 2020, up to 2055, the annual growth rate is 1.8% and 1.3% respectively for passenger and freight transport demand, with a much steeper increase until 2025 because of the end of the pandemic. In the WAM scenario the modal split remains substantially unchanged up to 2020 for passengers, whereas a significant increase in railway / ship goods transport is expected in the future. From 2020 to 2030, an increase of passenger-km in railway and public transport is expected.

Table 10.5 Transport demand for passengers and freights in WM and WAM scenarios

Scenario		Mode of transport		2015	2020	2025	2030	2035	2040	2045	2050
WM	Passenger	Road	billion pass-km	820.2	554.8	823.5	858.6	884.6	923.1	941.7	959.2
		Rail	billion pass-km	59.5	27.1	68.6	79	87.4	91	94.8	98.7
		Domestic aviation	Number of Landing and Take-Off cycle (LTO)	280.7	151.2	361.6	409.3	455.2	506.1	545.6	573.5
		International aviation	Number of Landing and Take-Off cycle (LTO)	425.4	172.8	560.2	635.4	713	793.6	849.7	908.0
		Total (excluding aviation)	**billion pass-km**	**879.7**	**581.9**	**892.1**	**937.6**	**972.1**	**1014.1**	**1036.5**	**1057.9**
	Freight	Road	billion ton-km	135.1	148.5	172	196	211.8	223.9	234.8	243.4
		Rail	billion ton-km	20.8	20.8	25.1	27.5	29	30.5	31.4	32.1
		Domestic navigation (inland waterways and national maritime)	billion ton-km	51.2	57.4	62	64.5	66.4	68.6	70.5	72.1
		Total	**billion ton-km**	**207.1**	**226.7**	**259.1**	**288**	**307.2**	**323**	**336.7**	**347.7**
WAM	Passenger	Road	billion pass-km	820.2	554.8	823.5	823.3	849.3	887.8	906.4	923.9
		Rail	billion pass-km	59.5	27.1	68.6	90.7	99.2	102.8	106.5	110.4
		Domestic aviation	Number of Landing and Take-Off cycle (LTO)	280.7	151.2	361.6	409.3	455.2	506.1	545.6	573.5
		International aviation	Number of Landing and Take-Off cycle (LTO)	425.4	172.8	560.2	635.4	713	793.6	849.7	908.0
		Total (excluding aviation)	**billion pass-km**	**879.7**	**581.9**	**892.1**	**914**	**948.5**	**990.6**	**1012.9**	**1034.4**
	Freight	Road	billion ton-km	135.1	148.5	172	146.4	156.6	166	175.2	182.4
		Rail	billion ton-km	20.8	20.8	25.1	77.1	84.2	88.4	91.1	93.1
		Domestic navigation (inland waterways and national maritime)	billion ton-km	51.2	57.4	62	64.5	66.4	68.6	70.5	72.1
		Total	**billion ton-km**	**207.1**	**226.7**	**259.1**	**288**	**307.2**	**323**	**336.7**	**347.7**

As concerns the agriculture sector, for the definition of activity data, the first step was to define the projection of livestock raised from 2025 to 2050. Scenarios of animal stocks were estimated from a model developed by ENEA[8], based on parameters such as demographic evolution, productions and food consumption of the population. Based on these parameters, indicators were constructed and through historical evolution and the use of statistical models[9], future evolutions were estimated. As regards parameters, specifically, meat production data were extracted from the EUROSTAT database[10], while meat consumption data were estimated from FAO production, import, export and stock data and verified with daily per capita consumption data[11].

Total meat consumption declined slightly from 2010 onward, mainly related to a reduction in beef consumption and, to a lesser extent, also pork consumption, while poultry meat consumption increased slightly. For dairy cows, the ratio of cow's milk production (accounting for about 94% of total milk produced) to total milk production was assumed to be essentially stable until 2050; the ratio of annual cow's milk production for the dairy industry to population was assumed in the scenarios to be about 250 kg per capita per year, following an upward trend observed since 2016. For laying hens, a slight increase in egg consumption per capita and a substantial stability (around unity) in the ratio of egg production to consumption (according to UNA and FAO statistics) was assumed. Ultimately, the result in the scenarios to 2050 is a decline in cattle and pig numbers and an increase in poultry, which are overall the most important animal categories in terms of emission impact. The consumption of synthetic nitrogen fertilizers significantly affects greenhouse gas emissions from the agriculture sector. This parameter was estimated based on projections by the European Synthetic Fertilizer Manufacturers' Association (Fertilizers Europe) [12], assuming an overall reduction in nitrogen consumption from 2020 to 2030 of 2%[13] . From 2030, the value of synthetic nitrogen fertilizer consumption varies depending on projections of agricultural production. For estimation of agricultural areas and productions, refer to LULUCF sector.

In Table 10.6, the assumptions adopted for synthetic fertilizers consumption and application of manure to agricultural soils are shown. An increase of 7% of the major nitrogen input to agricultural soils has been estimated in 2020 with respect to 2015 due to an 12% increase in the consumption of synthetic fertilizers (accounting for 32% of total nitrogen inputs in 2015) and an 2% increase of the application of manure to agricultural soils (accounting for 28% of total nitrogen inputs in 2015). The estimated reduction in synthetic fertilizer consumption falls, compared to 2020[14], by 2% to 2030. Agricultural areas and productions are stable overall in the scenarios.

8 *ENEA, 2006. Valutazione del potenziale di riduzione delle emissioni di ammoniaca. Final Report. ENEA UTS - PROT, Atmospheric Pollution Unit. September 2006; D'Elia, I., Peschi, E., 2013. Lo scenario emissivo nazionale nella negoziazione internazionale. ENEA Technical Report, RT/2013/10/ENEA.*

9 *The future evolution of the indicators was estimated using the Exponential Smoothing with dumped trend model with parameters estimated by maximum likelihood and the dumping parameter set equal to 0.85.*

10 https://ec.europa.eu/eurostat/data/database

11 https://www.fao.org/faostat/en/#data/FBS

12 https://www.fertilizerseurope.com/wp-content/uploads/2024/01/Forecast-2023-33-Studio-web.pdf

13 *The reduction in consumption, estimated by Fertilizers Europe, was actually about 18% as it was probably affected by the sharp reduction in 2022 recorded on products distributed nationwide by sellers to wholesale and/or retail establishments, farmers, etc., surveyed by ISTAT. This reduction, according to the National Fertilizer Manufacturers Association (Assofertilizzanti), is due to a postponement of fertilizer purchases, pending a reduction in prices.*

14 *The years 2021 and 2022 were two anomalous years with reductions from 2020 due to higher gas prices and temporary closure of production facilities.*

Table 10.6 Assumptions used for estimating GHG emission projections from synthetic fertilizers consumption and N input from application of manure

Major N input to agricultural soils (kt-nitrogen*)	2023	2025	2030	2035	2040	2045	2050
N input from application of synthetic fertilizers	493.7	571.7	565.9	566.1	566.8	566.6	565.2
N input from application of manure	414.7	483.4	467.6	466.5	464.6	461.5	456.3
Total consumption of N fertilizers	908.3	1,055.1	1,033.5	1,032.7	1,031.3	1,028.1	1,021.6

*Nitrogen content in synthetic and organic fertilizers

Source: ISPRA

In Table 10.7, assumptions for the main animal categories (cattle, swine, sheep and poultry) are shown. Cattle decrease in the scenarios, while swine rise in 2025 and then fall from 2030 and poultry rise until 2035 and then fall.

Table 10.7 Assumptions used for GHG emissions projections with respect to the number of animals

Animal category (kheads)	2023	2025	2030	2035	2040	2045	2050
Dairy cattle	1,574	1,570	1,528	1,507	1,495	1,482	1,463
Non-dairy cattle	4,008	3,897	3,839	3,811	3,792	3,764	3,717
Swine	9,171	8,864	8,676	8,587	8,534	8,466	8,358
Sheep	6,497	6,503	6,376	6,316	6,278	6,229	6,151
Poultry	173,372	183,123	184,202	184,514	184,341	183,305	181,168

Source: ISPRA

As concerns the waste sector, one of the main drivers of waste production is the population, already described above, but the reduction of emissions in the waste sector is mainly linked to the increase in separate waste collection and the subsequent recycling of the fractions collected separately. The year in which the most impactful policies and measures were applied was identified in 2005: the year in which the new law (Legislative Decree 13 January 2003 n. 36) on landfills and separate waste collection was applied in Italy. Consequently, the scenario was built according to the trend of waste management technologies in the years immediately following 2005 in relation to the trend in the years immediately preceding the same year. Obviously, the reduction of waste in landfill is strictly linked to the increase in composting and anaerobic digestion activities which have grown significantly since 2005. Activity data has been summarized in Table 10.8.

Table 10.8 Emissions drivers from waste management

	2023	2025	2030	2035	2040	2045	2050
Municipal solid waste (MSW) generation (kt)	29,142	29,088	29,007	28,950	29,610	29,426	29,109
Municipal solid waste (MSW) going to landfills (kt)	7,459	6,753	5,079	5,086	4,971	4,971	4,971

	2023	2025	2030	2035	2040	2045	2050
Share of CH_4 recovery in total CH_4 generation from landfills	45%	45%	45%	45%	45%	45%	45%

10.1.1 Energy industries

The far more relevant driving factor of emissions reduction is the further renewable development in the power sector. The additional measures for the electrification of final consumption push electricity production to grow faster than in WM, 2.2% per year from 2023 to 2055.

Additional measures are mainly addressed to boost photovoltaic and wind installations which together will represent over 93% of renewable installed capacity in 2055. The renewable capacity projected for 2030 and 2055 are about 135 GW and 288 GW respectively.

Figure 10.2 Renewable power and gross electricity production. The percentage represents the annual

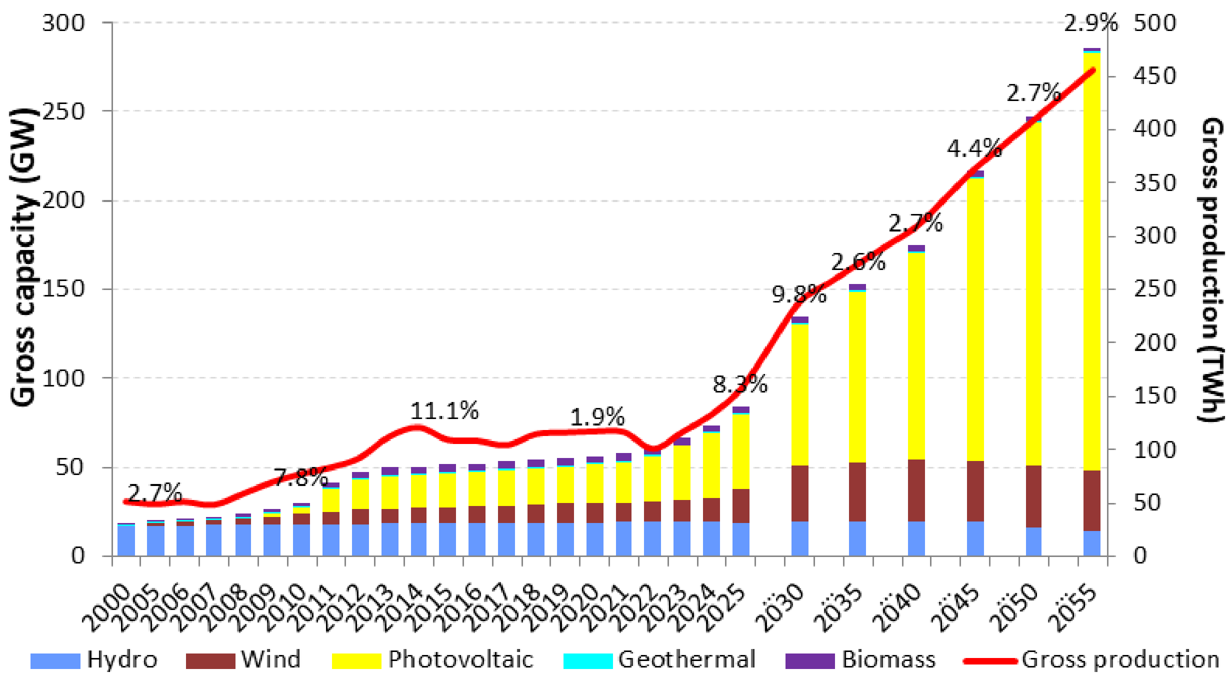
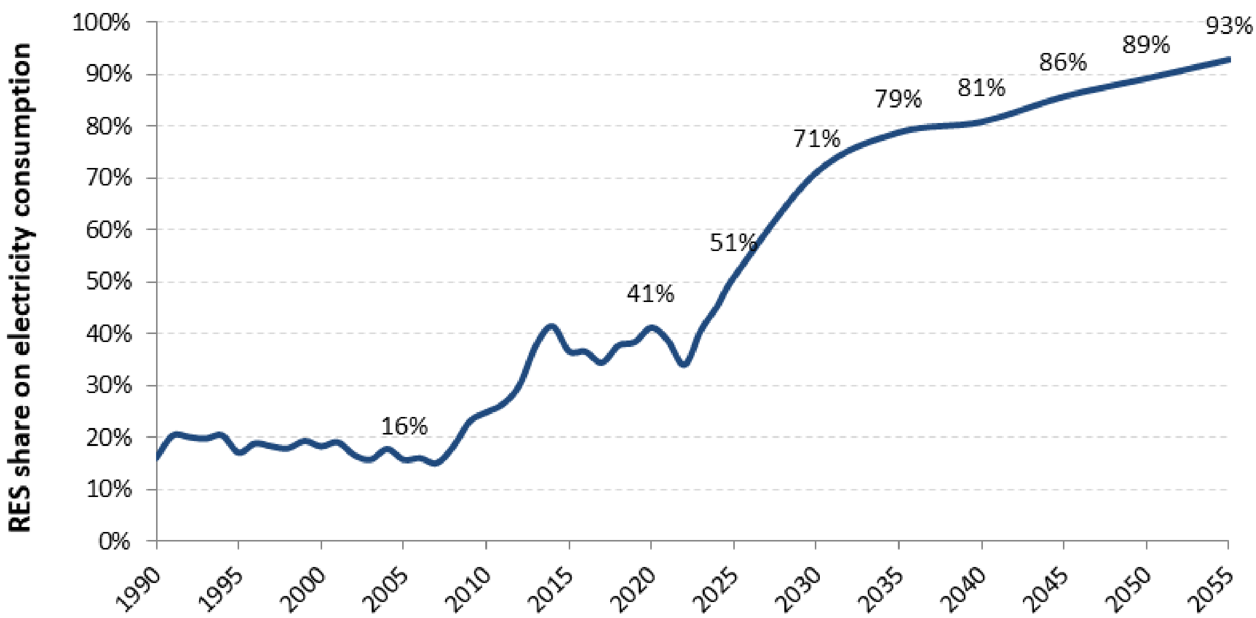


Figure 10.3 RES share in electricity consumption in the WAM scenario



The projection shows the increase of renewable share up to 93% in 2055, while 71% is reached in 2030, anticipating the outcome of WM reached in 2040. The renewable electricity production will amount to about 238 TWh in 2030 and 461 TWh in 2066, out of total generation of 324 TWh and 524 TWh, respectively, while the electricity consumption will be 335 TWh and 496 TWh, respectively. The renewable electricity production in WAM scenario is about 43% higher than WM scenario in 2030 and 54% on 2055.

10.1.2 Other sectors

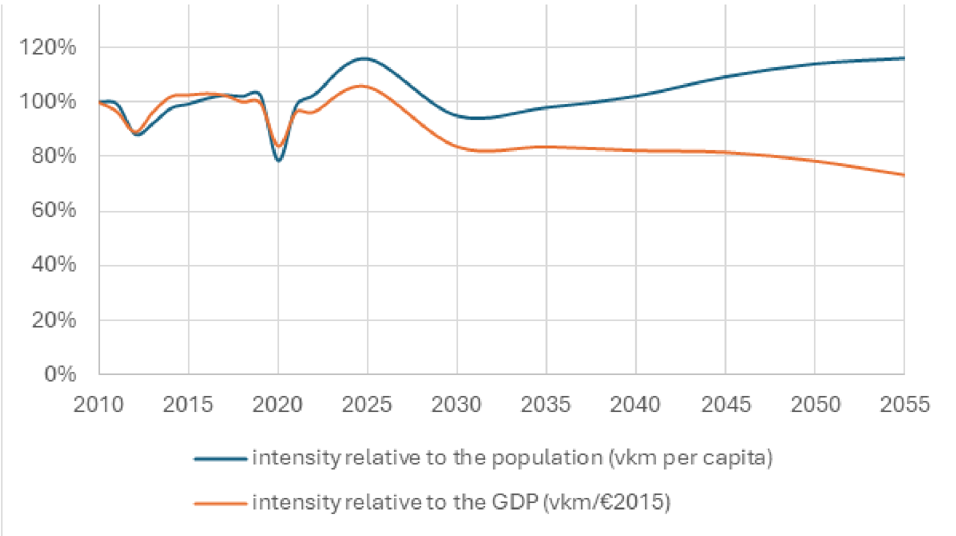
The strengthening of existing policies and actions, with the goal of reducing energy demand through energy efficiency and increasing the use of renewable sources for heat generation will continue in future years. The drivers to develop energy efficiency will be technological and behavioural evolution, possible only through the maintenance and strong enhancement of the existing promotion tools. It will be also essential to update current policies in order to increase the benefit-cost ratio for the State; to this end, a reform of fiscal incentives will be implemented to identify intervention priorities and differentiate the level of assistance based on the effectiveness in improving the building's energy performance, both in terms of consumption reduction and the increase in the use of renewable sources. The leading role of the Public Administration will have great importance, for which a major efficiency plan for the real estate portfolio and energy consumption reduction will need to be launched, including the sharing of targets with regional and local authorities. It will also be important to update existing measures to include the promotion of energy efficiency in buildings of the private non-residential sector, which still holds untapped potential for savings.

Regarding the thermal renewable sector, promotion tools will continue to be coordinated with the various measures planned for energy efficiency, particularly for buildings. These measures will include, for example, the obligation to integrate thermal renewable energy sources (RES) into buildings, the promotion of district heating, and the obligation to supply renewable heat. From a technological point will be important to continue creating a favourable framework to accelerate the decarbonization of residential consumption through widespread deployment of heat pumps in the civil sector, allowing the market to select the most efficient option for each application, while also valuing their contribution in cooling mode.

10.1.3 Transport

For passenger transport, the main driver is the growing share of zero-emission vehicles (target of 6.6 million electrified cars by 2030), the renewal of the local public transport fleet, increased use of renewable fuels, and additional measures to shift mobility demand, as outlined in the National Energy and Climate Plan. Furthermore, a further reduction in private mobility is expected due to the spread of smart working and the promotion of cycling and walking. From 2030 to 2055, the annual modal share for road and rail public transport is expected to increase by 2 percentage points compared to the WEM scenario. The effect of the planned measures also emerges from the time trend of vehicle kilometers (vkm) for passenger cars relative to the population and GDP (Figure26). By 2030, using 2010 as the base year, in the WAM scenario the intensity relative to the population is expected to be 95%, compared to 102% in the WM scenario. Similarly, the intensity relative to GDP is expected to be 84% in the WAM scenario, compared to 90% in the WM scenario (Figure 10.4).

Figure 10.4 Trends of intensity relative to the population (kvkm per capita) and GDP (vkm/k€2015)



Source: ISPRA

For freight transport, the reduction is primarily due to an increase in the modal share for rail transport (30% by 2030, Industrial Plan FS Group), incentive for the purchase of low-carbon light vehicles, reduction of empty truck trips (-5%) and the further development of biofuel use (bio diesel e bio GNL).An increase between 17% and 21% from 2030 to 2055, is expected in the annual modal share for rail and maritime freight transport compared to the WM scenario (Figure 10.5).

Figure 10.5 Trends of modal shift of freight transport (%)

Source: ISPRA

10.2 The harmonization process

The first step for the preparation of a new national emission scenario is to align at a given base year the latest national emission inventory submission and the GAINS-Italy emissions, estimated with a top-down approach. Being a Party of the United Nations Economic Commission for Europe (UNECE) Convention on Long Range Transboundary Air Pollution (CLRTAP), Italy has to annually submit an emission inventory of air pollutants and provide a report on its data according to the Guidelines for reporting emissions and projections data (UNECE, 2015). On the other hand, to produce a reliable emission scenario, GAINS-Italy model produces its own emission estimates, for the years considered in the model, with its own classification system. Discrepancies between the inventory and the GAINS-Italy output exist and are due to different reasons, such as, for example, different coverage and aggregation of emission sources, different emission calculation methodologies. These discrepancies need so to be solved and the emission estimates to be aligned. This alignment step is called harmonization and is needed to validate the emission scenario to base emission time trends in GAINS-Italy on a reliable starting point. In the harmonization process, activity data, emission factors and technologies for each sector are compared. If discrepancies emerge (for example in fuel allocation across sectors or different assumptions on control measures in place in the year of comparison), the model parameters will be modified according to the inventory with the attempt to let GAINS-Italy reproduce emissions as closely as possible to the national emission inventory. Further details about the harmonization method are reported in D'Elia and Peschi, 2013. For all these reasons, a comparison between the last national emission inventory, and the GAINS-Italy emission estimates has been carried out considering four historical years, 2005, 2010, 2015, and 2020. Results of the harmonization process between the 2025 emission inventory submission (INV_sub2025) and GAINS-IT estimates are summarized in Table 10.9.

Table 10.9 Comparison of total emissions in the last submission of the national inventory report (INV_sub2024) and GAINS-Italy estimates (GAINS-IT), for the years 2005, 2010, 2015 and 2020.

	Emissions 2005 (kt/yr)			Emissions 2010 (kt/yr)			Emissions 2015 (kt/yr)			Emissions 2020 (kt/yr)		
Pollutant	**INV_sub 2024**	**GAINS-IT**	**Δ (%)**	**INV_sub 2024**	**GAINS-IT**	**Δ%**	**INV_sub 2024**	**GAINS-IT**	**Δ (%)**	**INV_sub 2024**	**GAINS-IT**	**Δ (%)**
SO_2	411	413	0%	222	198	-11%	127	121	-5%	85	87	2%
NO_X	1291	1283	-1%	952	920	-3%	745	748	0%	596	642	8%
PM2.5	183	171	-6%	206	193	-6%	165	162	-2%	139	128	-8%
NMVOC	1322	1351	2%	1100	1123	2%	891	936	5%	815	833	2%
NH_3	470	467	-1%	413	409	-1%	391	396	1%	393	397	1%

Discrepancies in reproducing the national emission inventory have been considered acceptable if differences remain within a few percentage points. In the comparison, respect to the previous submission, NOx and NMVOC emissions from the agricultural sector have been considered in total emissions.

The following figures show a detailed analysis by sector. For all the pollutants, a good agreement also for individual sector has been obtained. In particular, the model shows a slight overestimate in SO_2 emissions for the sectors 1A1 and 1B and an underestimate for sector 2 maybe due to a different way to allocate energy consumptions. A good agreement has been reached for NOx especially in the base year 2005. PM2.5 shows a good agreement between the two estimates with the exception of the sector 6 – Other where the model estimates emissions from barbecue, fireworks not estimated in the inventory for their high uncertainties. The model shows a slight overestimate in NMVOC emissions from the sector 2 – Industrial process and solvent. The highest differences have been recorded for the year 2020, but due to the peculiarity of this year, all the differences have been considered in an acceptable range of uncertainty.

Figure 10.6 SO_2 emission harmonization between the national emission inventory submission 2025 and the GAINS_Italy estimates for the year 2005, 2015 and 2020.

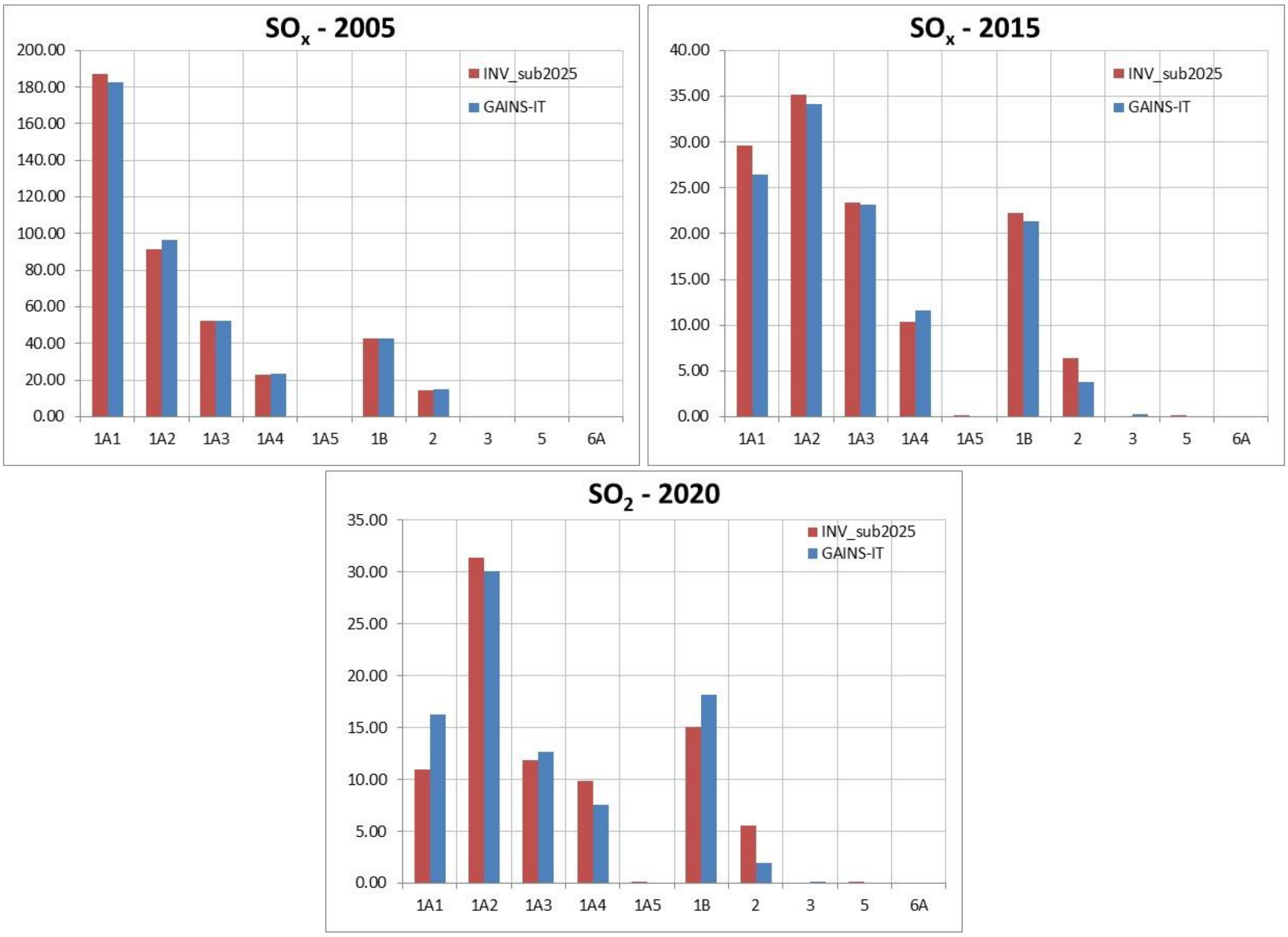


Figure 10.7 NO_X emission harmonization between the national emission inventory submission 2025 and the GAINS_Italy estimates for the year 2005, 2015 and 2020.

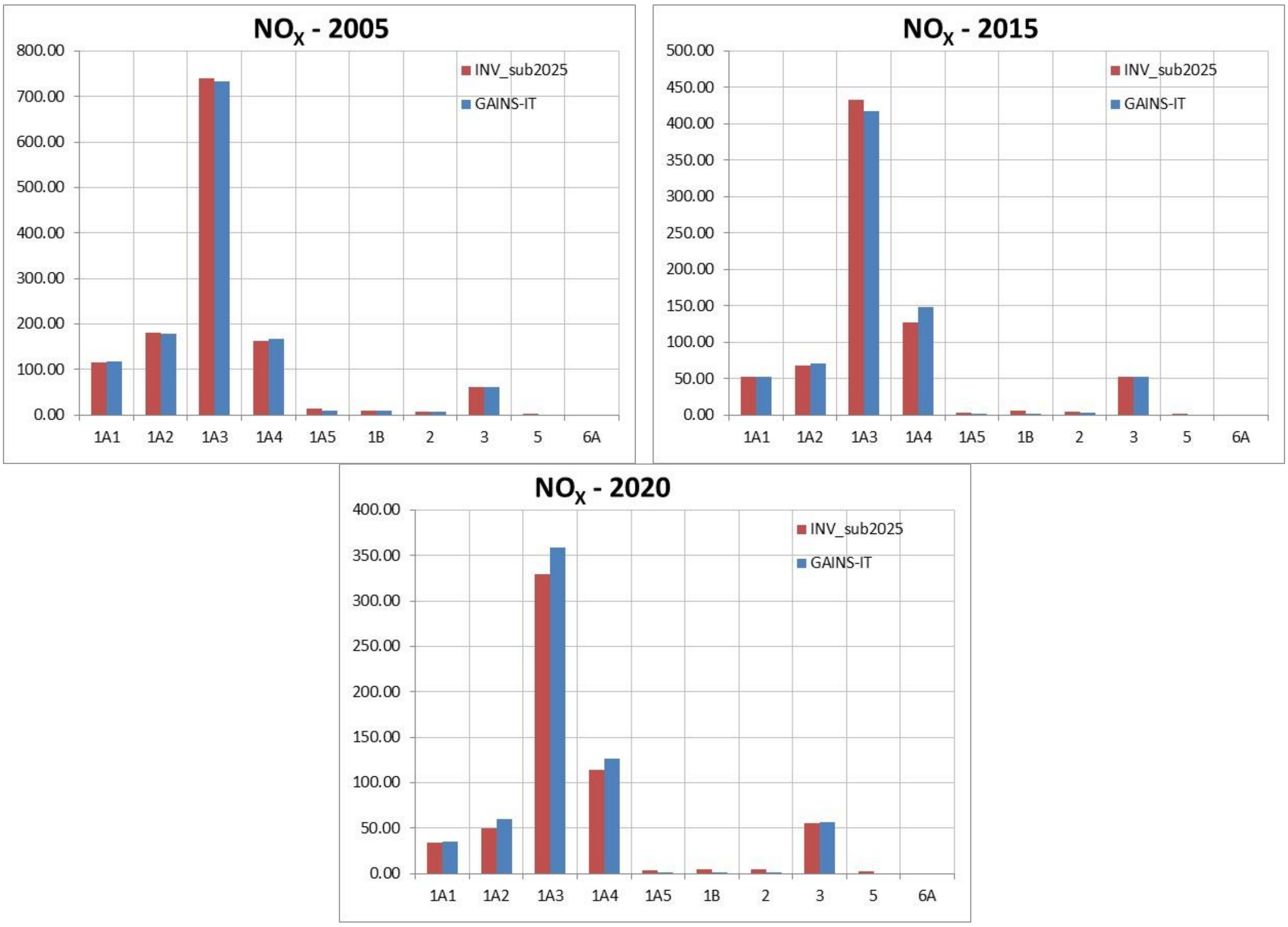


Figure 10.8 PM2.5 emission harmonization between the national emission inventory submission 2025 and the GAINS_Italy estimates for the year 2005, 2015 and 2020.

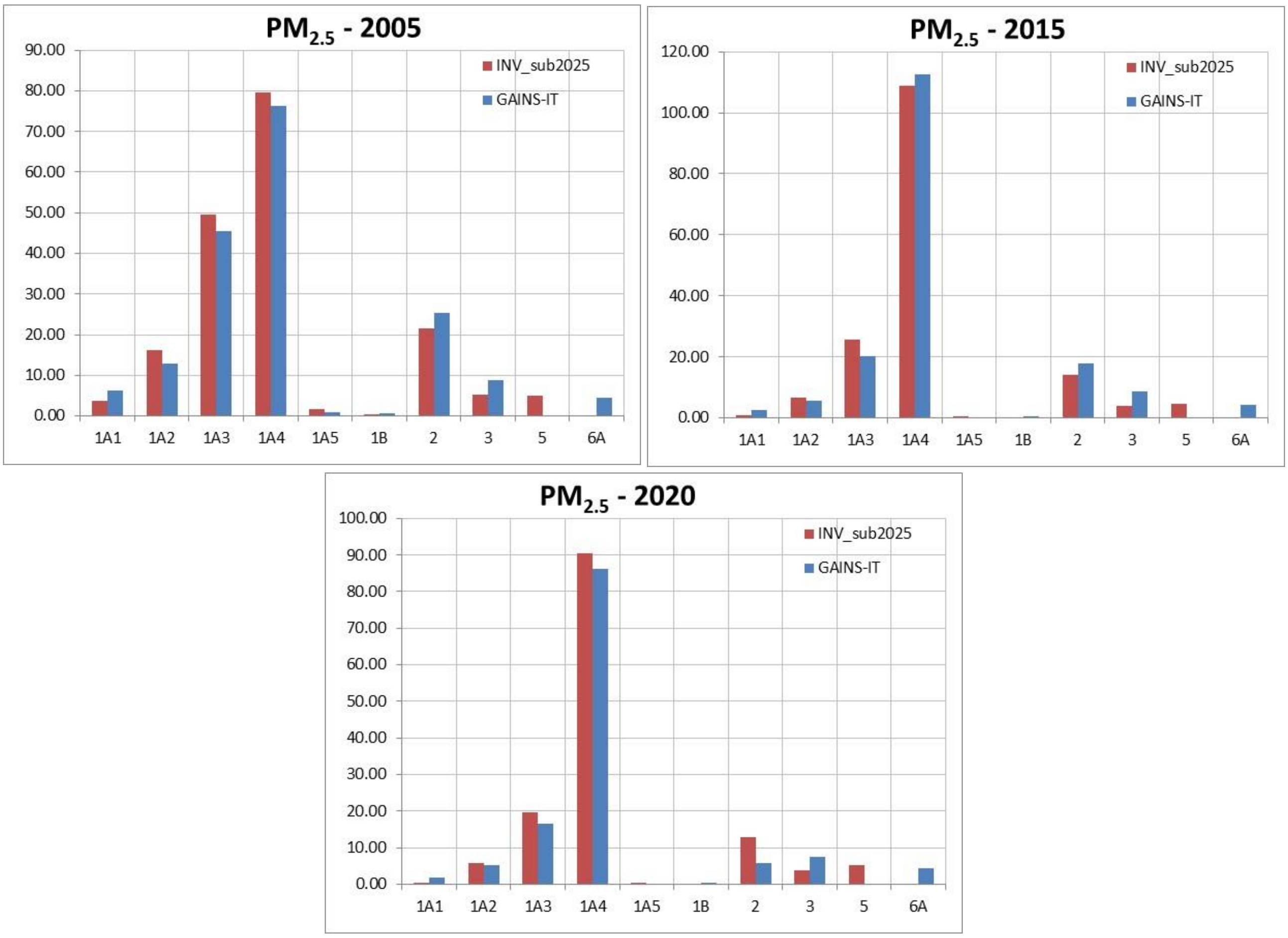


Figure 10.9 NMVOC emission harmonization between the national emission inventory submission 2025 and the GAINS_Italy estimates for the year 2005, 2015 and 2020.

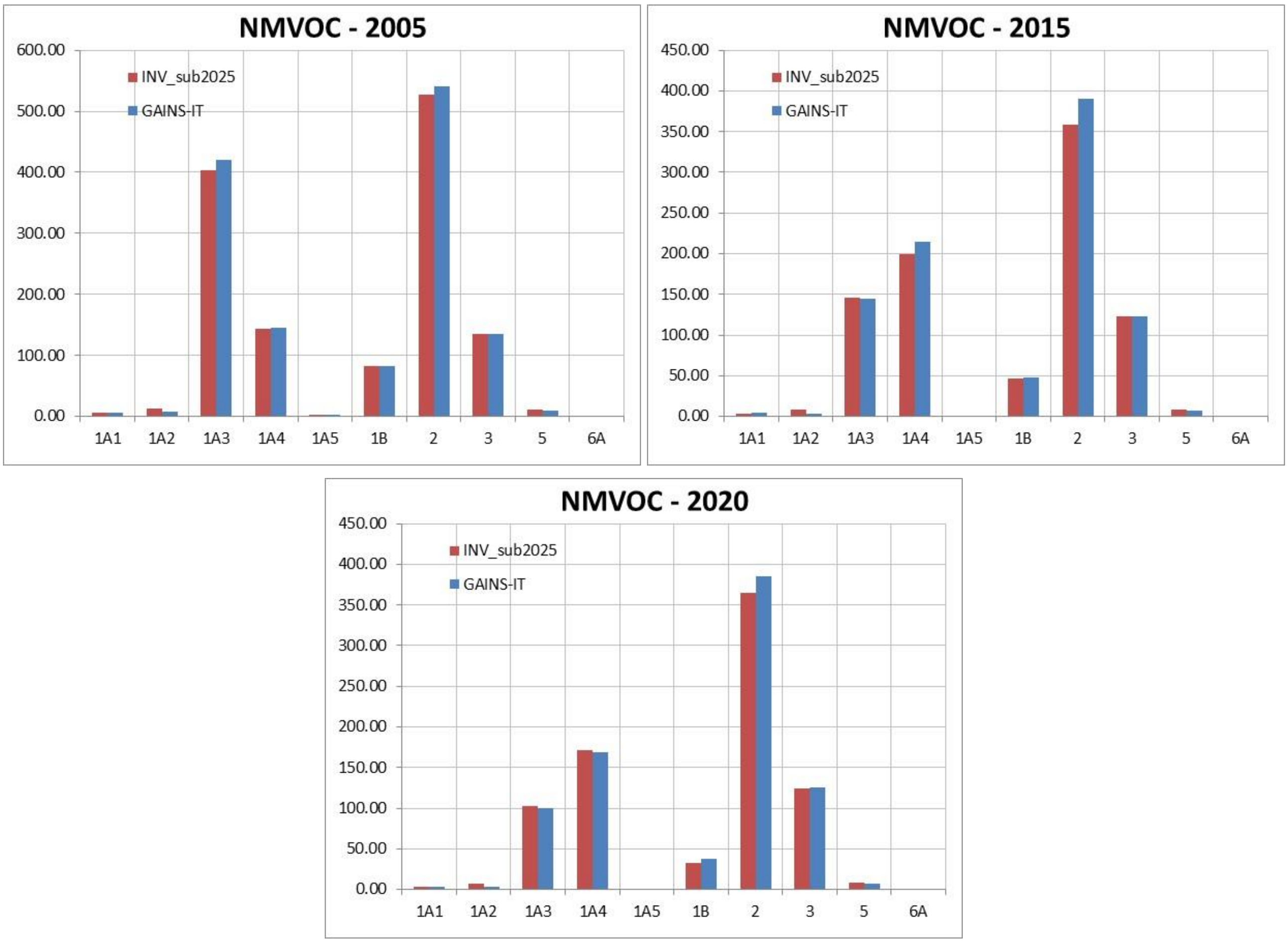
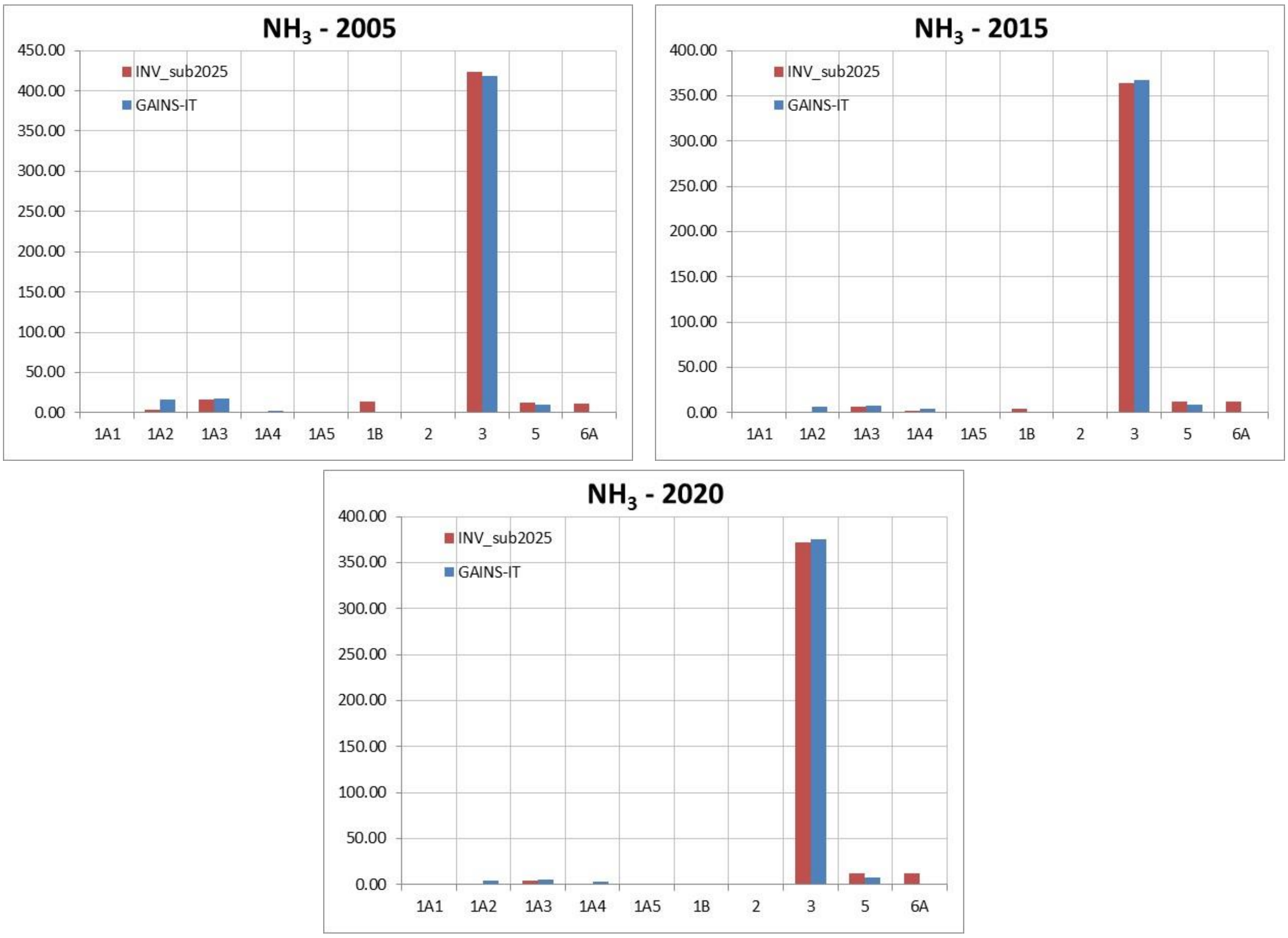


Figure 10.10 NH_3 emission harmonization between the national emission inventory submission 2025 and the GAINS_Italy estimates for the year 2005, 2015 and 2020.



10.3 The emission scenario

The result of the activity input scenarios and of the harmonization process is an emission scenario.

In the following figures, a comparison of the 2025 emission inventory submissions, the WM and WAM scenarios are presented for all the pollutants of the NEC Directive. Details by NFR sector are presented for the WM and WAM scenarios.

A huge decrease in SO_2 emissions is projected Figure 10. driven by the energy and the maritime sector for the year 2030 while the industrial sector (1A2) from the year 2030 onwards represents the main emitting sector (Figure 10.).

Figure 10.11 Reported (INV_sub2025) and projected (WM and WAM) SOx emissions elaborated by the GAINS-Italy model.

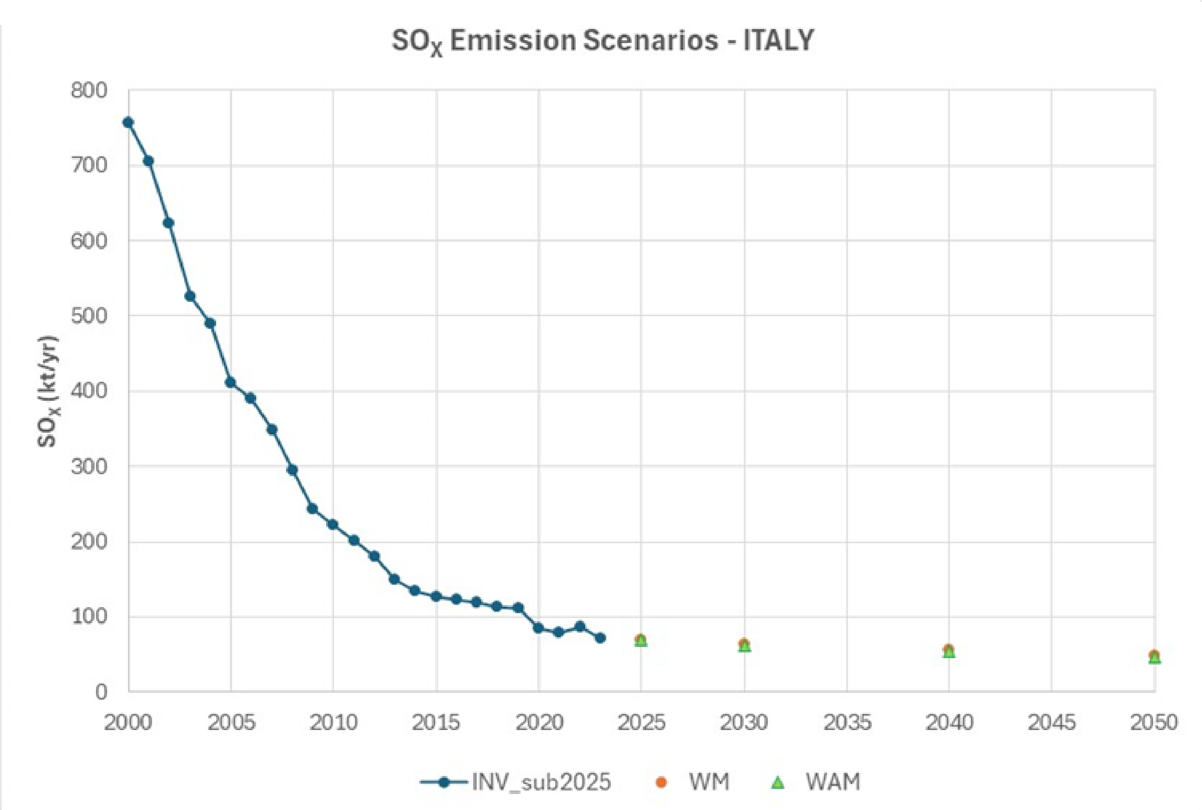
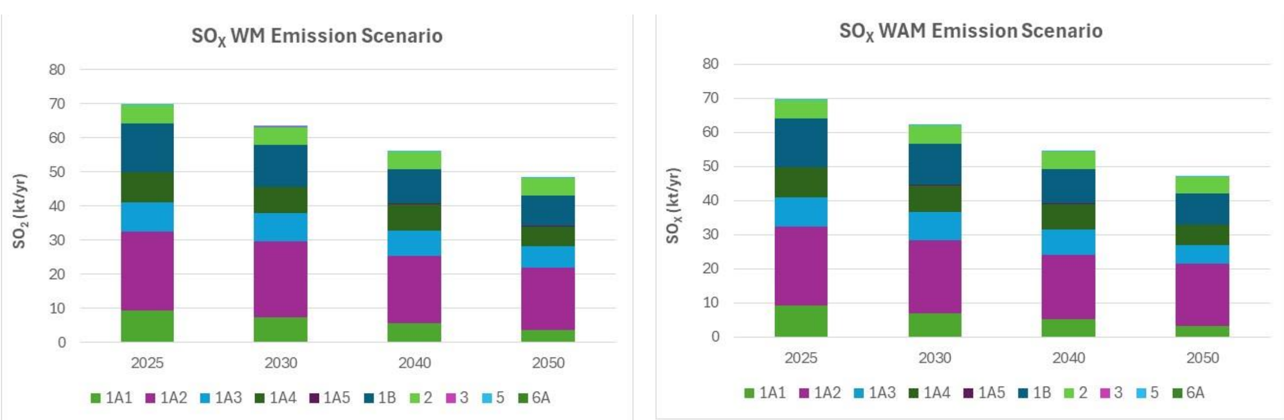


Figure 10.12 SOx emission scenario WM (on the left) and WAM (on the right) by sector.



A huge decrease is estimated in NOX emission scenarios (Figure 10.12) due to the diffusion of new diesel Euro 6 and electric vehicles. The road transport sector still represents the main NO_X source (Figure 10.11).

Figure 10.12 Reported (INV_sub2025) and projected (WM and WAM) NOx emissions elaborated by the GAINS-Italy model.

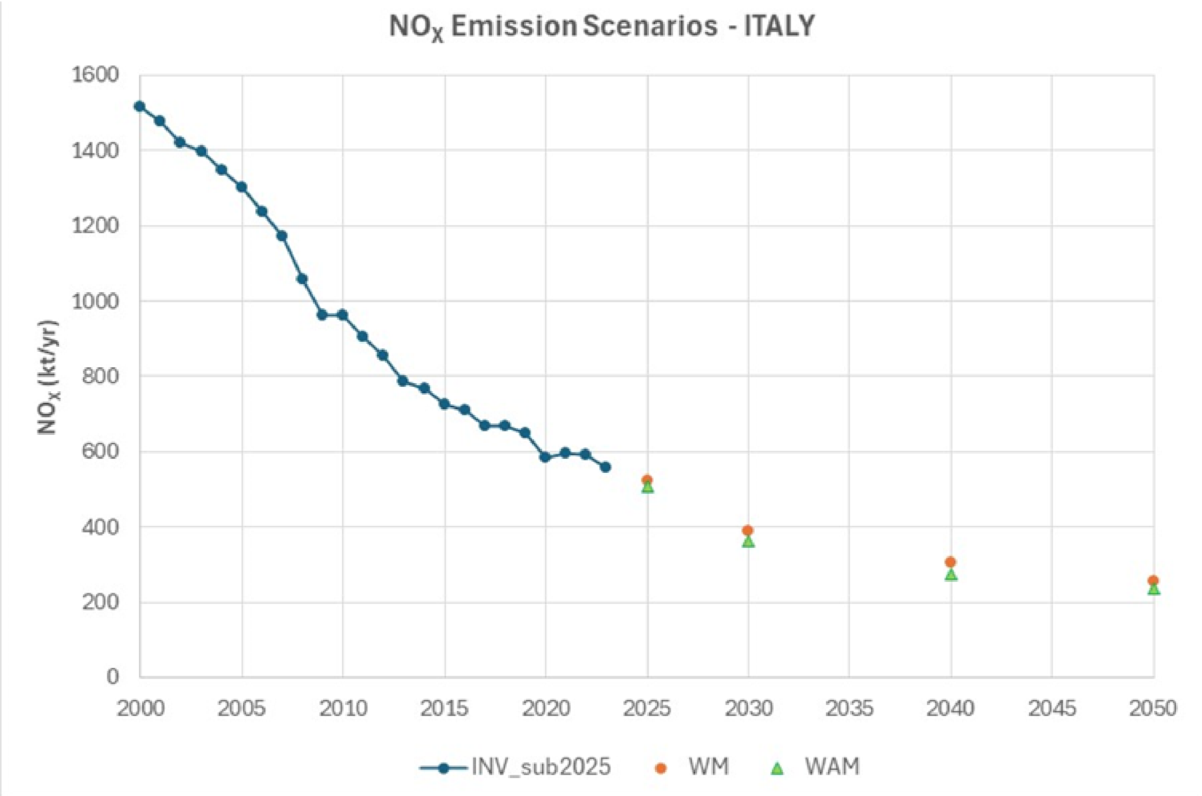
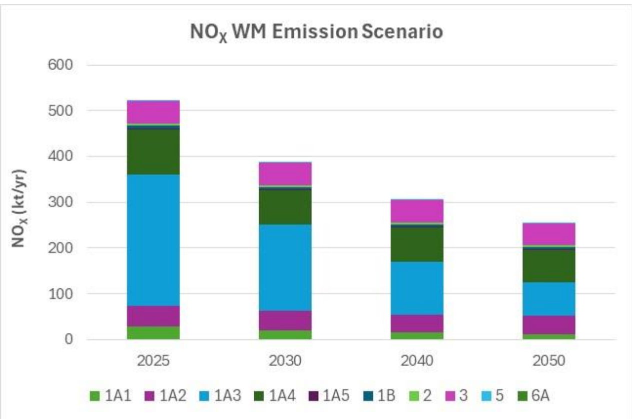
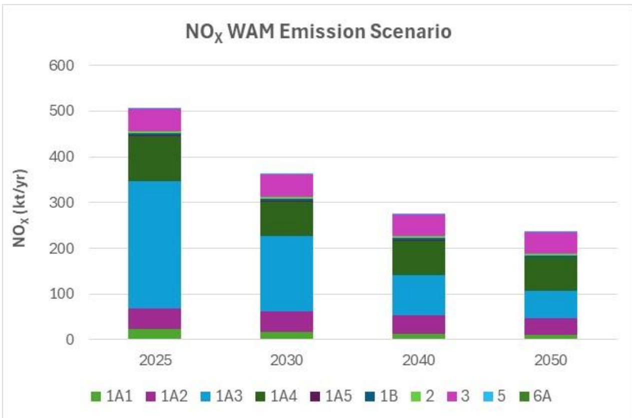


Figure 10.11 NOx emission scenario WM (on the left) and WAM (on the right) by sector.





The decrease of PM2.5 emissions (Figure 10.13) is driven by the civil sector (1A4) that continues to represent the main emitting sector (Figure 10.14).

Figure 10.13 Reported (INV_sub2025) and projected (WM and WAM) PM2.5 emissions elaborated by the GAINS-Italy model.

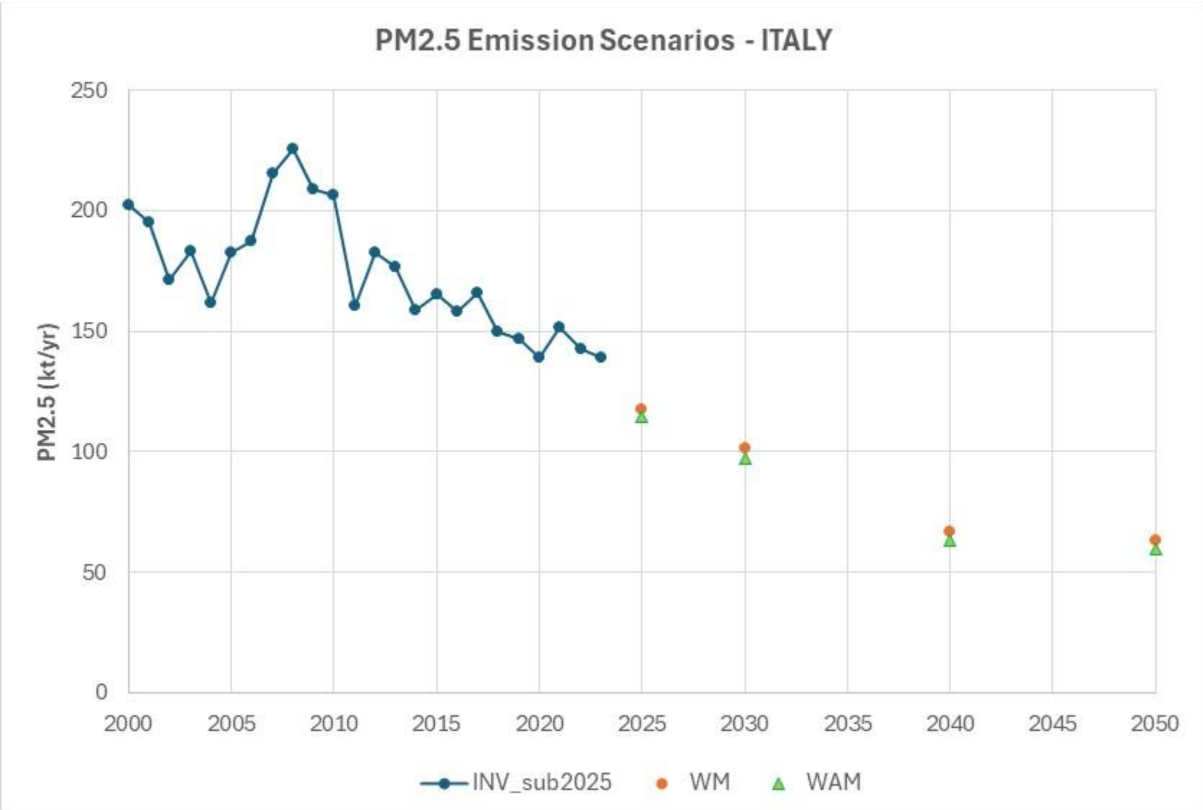
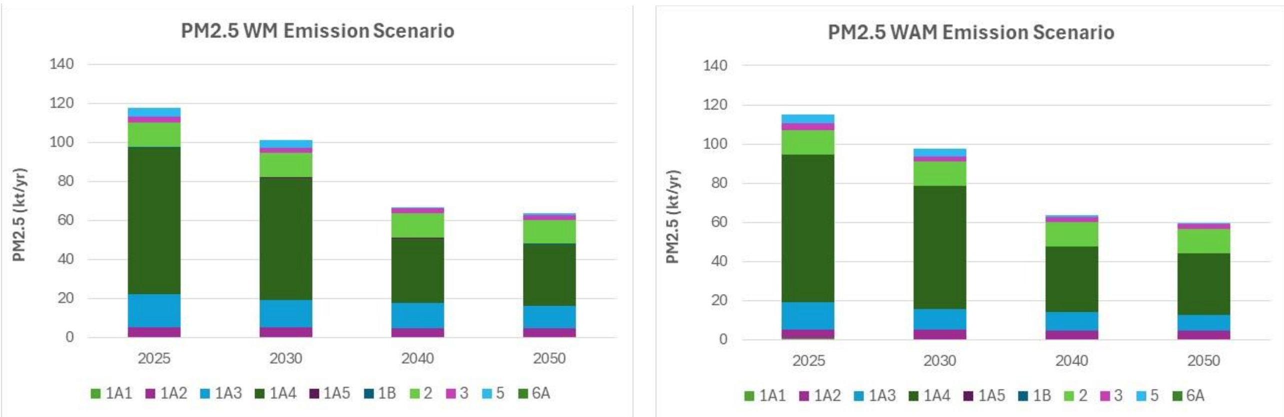


Figure 10.14 PM2.5 emission scenario WM (on the left) and WAM (on the right) by sector.



The decrease of NMVOC emissions (Figure 10.15) is driven by solvent (2) that will remain the main emitting sector (Figure 10.16).

Figure 10.15 Reported (INV_sub2025) and projected (WM and WAM) NMVOC emissions elaborated by the GAINS-Italy model.

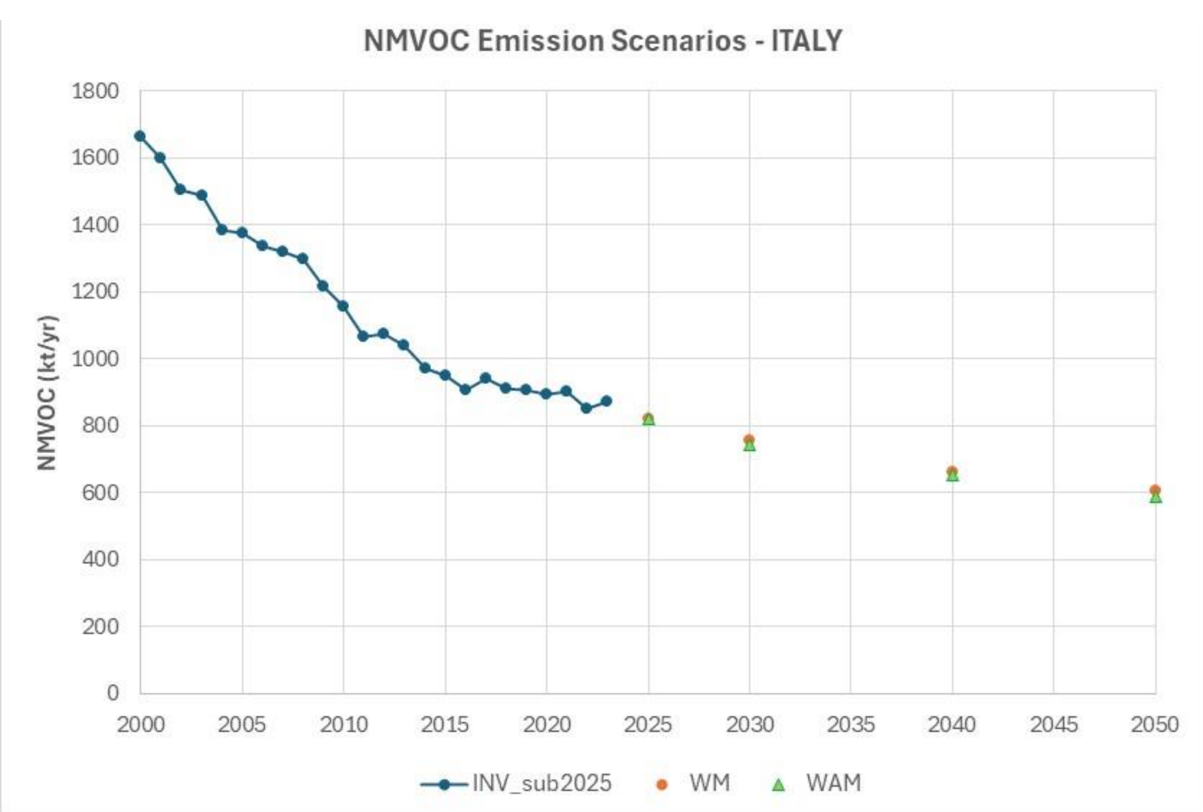
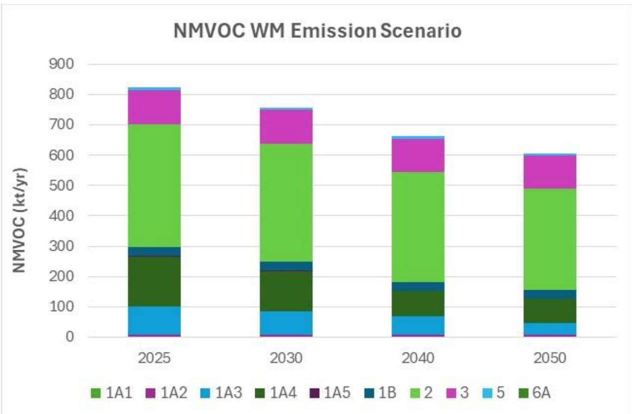
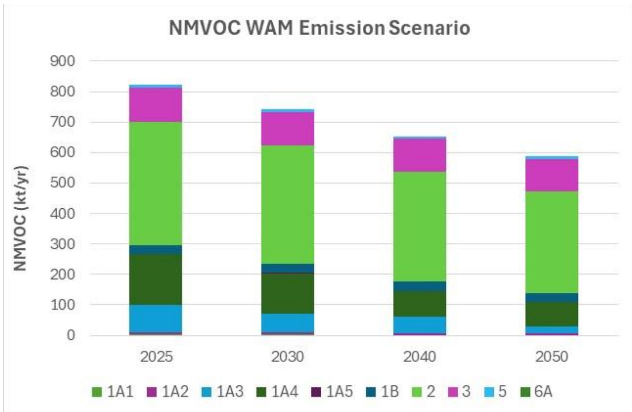


Figure 10.16 NMVOC emission scenario WM (on the left) and WAM (on the right) by sector.





NH_3 is the pollutant with less variations (Figure 10.17)) whose main contribution to total NH3 emissions is due by the agricultural sector (Figure 10.18).

Figure 10.17 Reported (INV_sub2025) and projected (WM and WAM) NH3 emissions elaborated by the GAINS-Italy model.

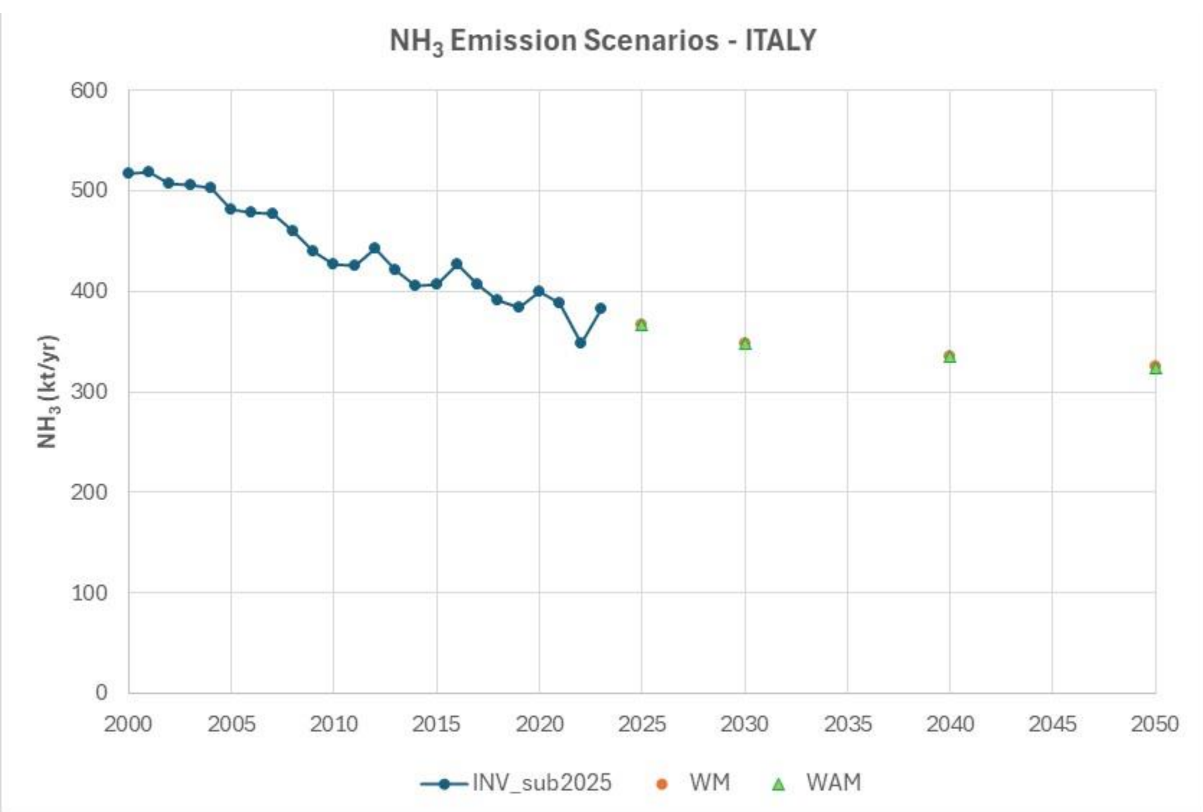
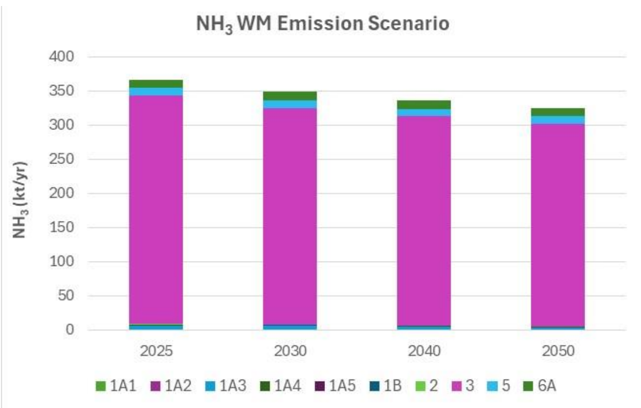
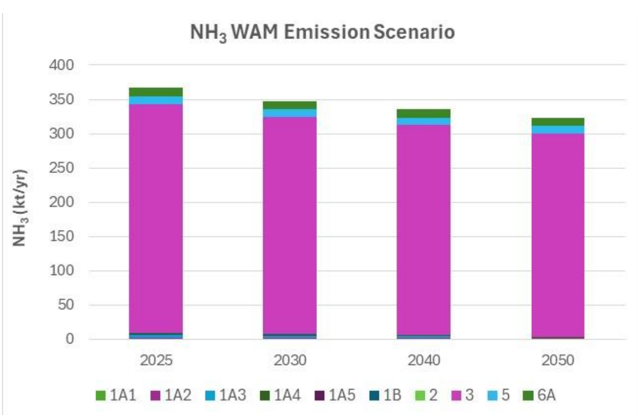


Figure 10.18 NH_3 emission scenario WM (on the left) and WAM (on the right) by sector.





10.4 The NEC emission target

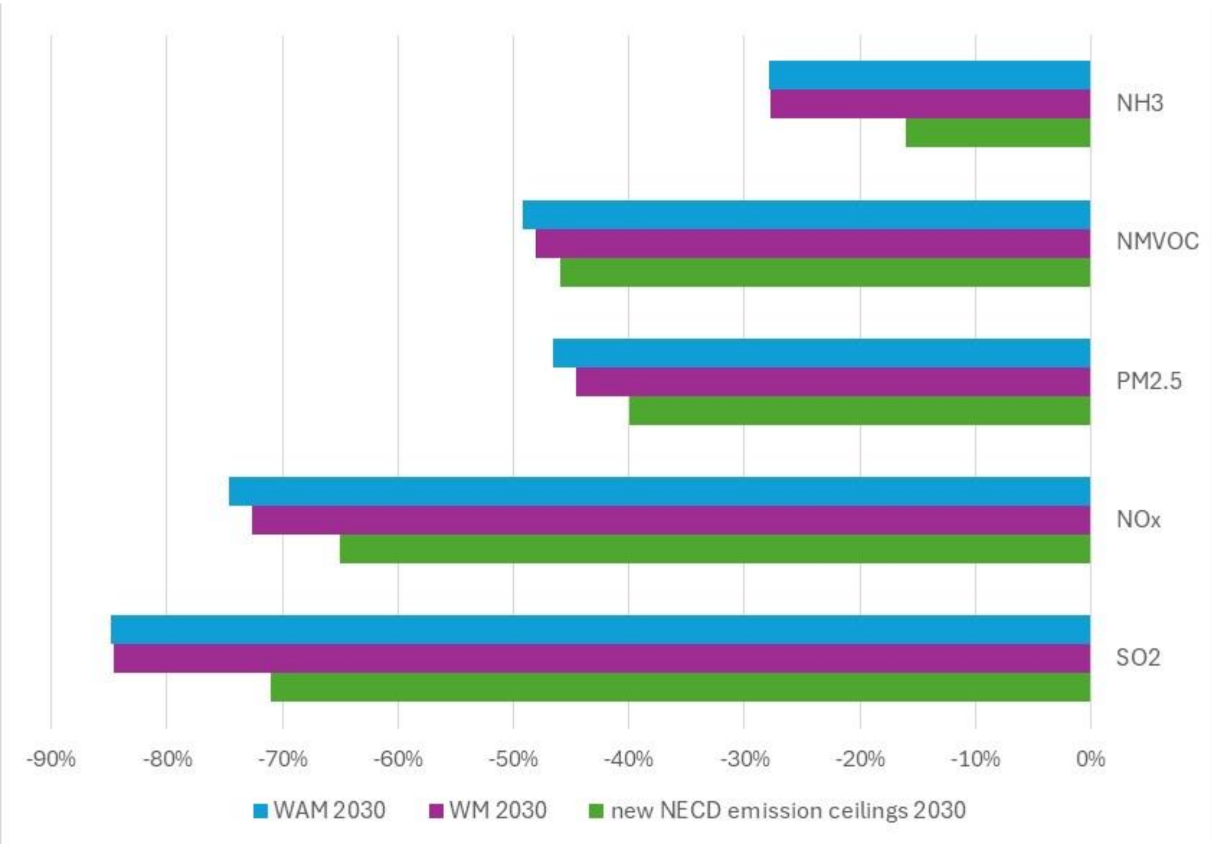
The NEC Directive (EU, 2016), implemented in the Italian legislation in the D.Lgs. 81/2018, defines for each Member States the emission reduction targets in the year 2020 and 2030 respect to the base year 2005 for the anthropogenic emissions of SO_2, NOX, PM2.5, NMVOC and NH_3.

In Table 10.10 and Figure 10.19 the attainment of the national emission reductions in the year 2030 in comparison with the National Emission Ceilings Directive (NECD) targets is reported.

Table 10.10 National emission reductions in the year 2030 respect to the base year 2005 and comparison with the National Emission Ceilings Directive (NECD) targets.

	new NECD emission ceilings 2030	WM 2030	WAM 2030
SO_2	-71%	-85%	-85%
NOx	-65%	-73%	-75%
PM2.5	-40%	-45%	-47%
NMVOC	-46%	-48%	-49%
NH_3	-16%	-28%	-28%

Figure 10.19 National emission reductions in the year 2030 respect to the base year 2005 and comparison with the National Emission Ceilings Directive (NECD) targets.



According to the present emission projections, at the year 2030, the WM scenario could attain the emission target for all the pollutants. Additional measures in the WAM scenario have been considered especially in the road transport sector where a higher electric vehicles spread is foreseen.

11 REPORTING OF GRIDDED EMISSIONS AND LPS

Every four years, from 2017 with reference to 2015 emissions, ISPRA shall provide the disaggregation of the national inventory at provincial level as instituted by the Legislative Decree n. 81 of 30 May 2018. The emissions disaggregated at regional and provincial levels are compared to the results obtained by regional bottom-up inventories. Emissions disaggregated at local level are also used as input for air quality modelling. Methodologies and proxies are described in the relevant publication (ISPRA, 2009) (ISPRA, 2022) available on: https://emissioni.sina.isprambiente.it/inventari-locali/ .

Simultaneously, ISPRA carries out the spatial disaggregation of national emissions on the 0.1x0.1° EMEP grid.

The grid definition for a country contains a dataset for each grid cell with information about (CEIP, 2019):

- the country or area (ISO2 or a three digits abbreviation for countries and other areas which you can see in the column Country code in the grid definition table above)
- the country-or area name
- the longitude position of the grid cell (centre of the cell)
- the latitude position of the grid cell (centre of the cell)
- and fraction of the grid cell (share of the cell area which belongs to the country/area, e.g. 1 for cells which are completely inside the country/area borders and e.g. 0.5 for cells where half of the area belongs to the country/area and the rest is outside the boundary)

According to the review process (EEA, 2020), the reporting of gridded data has been aligned with the last available reporting guidelines and the relevant GNFR codes in the next submission, as it is indicated in the Table 11.1. Proxy variables used for disaggregation have been reported too.

Table 11.1 Aggregation for Gridding and LPS of NFR sector

NFR Aggregation for Gridding and LPS (GNFR)	Proxy
A_PublicPower	point sources consumptions from ETS/LPS, see paragraph "LPS data"
B_Industry	combustion in industry prevalently point sources consumptions data from ETS/LPS, where not available production data. For industrial processes prevalently production data from E-PRTR or producers associations, in a few of case production capacity or data about employees at NUTS3 level, see paragraph "LPS data".
C_OtherStationaryComb	resident people and fuels sold at NUTS3 level
D_Fugitive	see paragraph "fugitive"
E_Solvents	prevalently employees at NUTS3 level. Data from the national institut of statistics (ISTAT)
F_RoadTransport	see paragraph "transport"
G_Shipping	see paragraph "transport"
H_Aviation	see paragraph "transport"
I_Offroad	see paragraph "transport"
J_Waste	amount of managed waste at NUTS3 level on the basis of the management system for SWDS, biological treatments and incineration. Source: ISPRA. For domestic wastewater resident people at Nuts3 level while data about employees at NUTS3 level in the case of industrial wastewater have been used. Source: ISPRA.
K_AgriLivestock	see paragraph "agriculture"
L_AgriOther	see paragraph "agriculture"
M_Other	
N_Natural	

NFR Aggregation for Gridding and LPS (GNFR)	Proxy
O_AviCruise	see paragraph "transport"
P_IntShipping	see paragraph "transport"
z_Memo	

The methodologies for spatial disaggregation are consistent with those reported in the EMEP/EEA 2019 Guidebook and described in relevant report (ISPRA, 2009). National emissions have been disaggregated at provincial level (NUTS3) because of the availability of proxy data, then the allocation to the 0.1x0.1° grid has been realized on the basis of the 2019 EMEP/EEA Guidebook (EMEP/EEA, 2019). In particular, point sources have been allocated directly to the grid within which they are contained by converting the x, y values to that of the coordinates used to geo-reference the grid. For area sources (NUTS3 polygons) the fraction of the area of the polygons has been used to distribute the emissions from the original polygon to the intersected grid cell. Finally, the spatially resolved (mapped) detailed NFR sectors have been aggregated in the GNFR code.

Regarding solvent use, the main proxy families used are demographics (population) and employees in specific production activities (number of employees per ATECO code). The other pollutants characteristic of the macrosector are CO_2 and benzene although the introduction of some new emission categories such as the use of tobacco or explosives has led to the estimation of emissions of other pollutants such as metals and particulate matter. Further information is reported in ISPRA (ISPRA, 2022)

11.1 FUGITIVE

Proxy used for disaggregation of 1B1 and 1B2 are reported in the Table 11.2.

Table 11.2 Proxy for the disaggregation of fugitive emissions

Category	Proxy
1 B 1 a (SNAP 050102)	Amount of coal production
1 B 1 a (SNAP 050103)	Amount of solid fuels consumption from ETS plants
1 B 2 a iv	Amount of crude oil refined at plant level
1 B 2 a v (SNAP 050502)	Amount of gasoline sold at provincial level.
1 B 2 a v (SNAP 050503)	Amount of mineral oil and LPG in depots for industrial and services at regional level distributed according to the amount of gasoline sold at provincial level.
1 B 2 b (SNAP 050601)	Amount of natural gas consumption in the compressor stations (ETS data)
1 B 2 b (SNAP 050603)	Amount of natural gas provided to the distribution network at provincial level (other destination than industrial and thermoelectric users)
1 B 2 c	Amount of crude oil refined at plant level

11.2 TRANSPORT

Proxy used for disaggregation of the different transport mode are reported in the Table 11.3.

Table 11.3 Proxy for the disaggregation of transport emissions

Category	Proxy
1A2gvii	ISPRA study about industrial machinery data elaborated at NUTS 3 level.
1A3ai(i)	Emissions deriving from international LTO, in the detail of Italian airports, elaborated by Eurocontrol to the aim of the estimation of emissions from aviation for Member Countries Inventories, then aggregated at NUTS 3 level.
1A3aii(i)	Emissions deriving from domestic LTO, in the detail of Italian airports, elaborated by Eurocontrol to the aim of the estimation of emissions from aviation for Member Countries Inventories, then aggregated at NUTS 3 level.
1A3bi	Ministry of Transport data about passenger cars fleet at NUTS 3 level, according to Copert classification; traffic flows and length of motorway sections as regards highway share.
1A3bii	Ministry of Transport data about light duty vehicles fleet at NUTS 3 level, according to Copert classification; Value added as regards urban and rural share; traffic flows and length of motorway sections as regards highway share.
1A3biii	Ministry of Transport data about vehicles fleet at NUTS 3 level, according to Copert classification; Value added as regards urban and rural share for heavy duty vehicles; traffic flows and length of motorway sections as regards highway share.
1A3biv	Ministry of Transport data about mopeds and motorcycles fleet at NUTS 3 level, according to Copert classification; traffic flows and length of motorway sections for motorcycles categories as regards highway share.
1A3bv	Same proxies as gasoline vehicles categories. Evaporative emissions are added to those due to combustion, for each vehicle category, according to Copert classification, for each driving cycle, therefore disaggregated at NUTS 3 level according to the criterion used for other road transport activities. Therefore emissions related to this activity are included in the other NFR classes.
1A3bvi	Same proxies as corresponding vehicles categories, according to Copert classification. Non exhaust emissions are added to those due to combustion, for each vehicle category, according to Copert classification, for each driving cycle, therefore disaggregated at NUTS 3 level according to the criterion used for other road transport activities. Therefore emissions related to this activity are included in the other NFR classes.
1A3c	Ministry of Transport data about the length of non-electrified railway sections, relating to Italian State Railways Group and to the Regional and/or local railways network, elaborated at NUTS 3 level.
1A3dii	Data elaborated at NUTS 3 level covering: Eurostat data about vessels, by type, in harbours ; ships berths for: sailing boats, motorboats, watercrafts; simplified trajectories for cruise; inland waterways traffic is estimated by attributing a share to freight traffic (provinces of the Po basin) and a share to passenger traffic on the basis of Ministry of transport data about the number of boats for province.
1A4bii	Data at NUTS 3 level about mechanical means used, deriving from surveys on the structure and production of farms, performed by the Italian Institute of Statistics.
1A4cii	Data at NUTS 3 level about mechanical means used, deriving from surveys on the structure and production of farms, performed by the Italian Institute of Statistics.
1A4ciii	Data, from Economic Observatory on the production structures of maritime fishing in Italy, about fishing boats number and consumptions at NUTS 3 level.
1A5b	National Institute of Statistics data about resident population at NUTS 3 level have been used as proxy for military mobile activities.

11.3 AGRICULTURE

Proxy used for disaggregation of the agriculture sector are reported in the Table 11.4. The methods used for gridding are reported below Table 11.1 and are the same for all inventory sectors.

Table 11.4 Proxy for the disaggregation of agriculture sector

Category	Proxy
3Da1	Quantity of annual nitrogen fertilizers (tons) distributed in the italian provinces (National Institute of Statistics - ISTAT); for CO_2 from liming: annual amount of lime and dolomite distributed (ISTAT); for CO_2 from urea application: annual amount of urea distributed (ISTAT)
3C	Cultivated area (hectares) for the production of rice (ISTAT)

Category	Proxy
3Da2, 3Da3, 3De	The activity includes estimates of emissions from spreading livestock manure, grazing, nitrogen-fixing process of leguminous crops (NH_3 emissions only), use of other organic fertilizers (compost, other soil conditioners, animal and vegetable processing wastes, other), agricultural sludge spreading, soil input from crop residues (N_2O emissions only), and cultivation of organic soils (N_2O emissions only). NMVOC emissions arise only from the spreading of livestock manure and from grazing. Provincial data used for disaggregation are: agricultural area used (hectares) and annual production harvested (tons), number of livestock, organic fertilizers used, tons of sludge spread in agriculture, area of leguminous crops most cultivated (alfalfa, soybean, clover, grain bean), organic soils. National emissions from this sector were disaggregated proportionally to: agricultural area used for legumes; livestock stock for emissions from grazing and manure spreading; agricultural production for emissions from nitrogen contributed by crop residues; amount of sludge spread on agricultural soils and agricultural area used for emissions from the use of sewage sludge; amount of organic manures and soil conditioners for emissions from the distribution of other organic fertilizers; provincial areas of organic soils for emissions generated by this type of soils. As for provincial NH_3 emissions from spreading, a provincial distribution was constructed of emissions from spreading from the provincial distribution of total ammonia emissions (i.e., from sheltering, storage, spreading, and grazing) by animal category and the percentage of emission from spreading (calculated considering the emission factors of the four stages of manure management). The provincial distribution of emissions total ammonia emissions was calculated from the provincial emission factors (totals of the four stages of management of manure) compiled by CRPA (in a 1997 study), to which a variation was applied based on the emission factors updated by animal category (but constant for all provinces), and the provincial animal numbers from ISTAT sources. For the disaggregation of emissions from grazing, the same procedure as for spreading was used as just described. As for provincial emissions of N_2O, NO_x and NMVOC from grazing and spreading, a provincial distribution of nitrogen excreted at grazing and shelter separately, based on the coefficients of nitrogen excreted at grazing and sheltering by animal category and the provincial distribution of livestock numbers from ISTAT sources. The provincial distribution of nitrogen at shelter was used to disaggregate emissions from spreading.
3F	Annual production of cereal harvest (quintals) (ISTAT)
3A1	For cattle, provincial emissions were estimated by multiplying the number of heads available at provincial level (ISTAT) by the provincial emission factors from a 1994 study (Research Centre on Animal Production - CRPA). National emissions were then disaggregated on the basis of these provincial emissions
3A	Number of heads available at provincial level (ISTAT)
3B	As regards CH_4, COVNM, PM10, PM2.5, NH_3, NO_x emissions, national emissions for cattle and swine are estimated according to IPCC and EMEP/EEA for manure management (housing and storage) and were distributed by province based on the number of livestock. The 2013 Farm Structure Survey (FSS) data were used to disaggregate 2015 national emissions, and the 2016 FSS was used for 2019 emissions. NMVOC emissions from storage were disaggregated based on the distribution provincial emissions of NMVOCs from storage, processed with provincial emission factors for cattle and swine, estimated by CRPA in a 1997 study, and provincial consistencies from ISTAT sources. Emissions of NH_3 from shelter and storage were disaggregated by constructing two distributions of provincial emissions from sheltering and storage separately. The procedure for calculating these distributions is the same as that used for spreading and described in SNAP category 1002 with respect to the emissions of NH_3. Considering emissions for buffalo, sheep, goats, equines, poultry, rabbits, fur animals national emissions are estimated according to IPCC and EMEP/EEA for manure management (housing and storage) and were distributed by province based on the number of animals. The 2013 FSS data were used to disaggregate 2015 national emissions, and the 2016 FSS was used for 2019 emissions. NMVOC emissions from storage were disaggregated based on the provincial distribution of methane emissions from storage, compiled with 2006 IPCC emission factors by climate band (Cool (<15°C) and Temperate (15 to 25°C)) and provincial consistencies from ISTAT sources. NH_3 emissions from shelter and storage were disaggregated by constructing two distributions of provincial emissions from shelter and storage separately. The procedure for calculating these distributions is the same as that used for spreading and described in the SNAP category 1002 with respect to emissions of NH_3.

Category	Proxy
	As regards N2O emissions, due to animal manure stored, were distributed at the provincial level, starting in 2000, based on the provincial distribution of nitrogen excreted at the shelter, estimated with the coefficients of excreted nitrogen at the shelter and the provincial distribution of the number of animals by animal category. For the years 1990 and 1995, national emissions were disaggregated with the distribution of provincial N2O emissions from storage, estimated by CRPA.
3Df	Data on the provincial sale of pesticides containing HCB (ISPRA elaborations on ISTAT data)
5C2	Annual production of cereal and woody crops harvest (quintals) (ISTAT)

11.4 LPS DATA

GNFR	n° plant	Height class/n°
A_PublicPower	207	2/194; 4/4; 5/9
B_Industry	330	1/328; 4/2
D_Fugitive	117	1/117
G_Shipping	77	1/77
H_Aviation	106	1/106
I_Offroad	22	1/22

LPS data for the year 2019 have been submitted in 2021. A brief description of data is reported in the following.

Table 11.5 Number of plants and relevant height class

GNFR	n° plant	Height class/n°
A_PublicPower	207	2/194; 4/4; 5/9
B_Industry	330	1/328; 4/2
D_Fugitive	117	1/117
G_Shipping	77	1/77
H_Aviation	106	1/106
I_Offroad	22	1/22

Following the review process, some errors on longitude and latitude of plants have been corrected, also thanks the implementation procedures of the IED (Industrial Emissions Directive) European Directive.

Italy has decided not to provide all and only PRTR data as LPS data as in Italy some PRTR categories do not respond to the characteristics of large point sources. This is especially true for farms that cannot be considered large point sources and therefore have been eliminated with respect to the previous submission. The current submission is instead consistent with gridded data and includes sources outside of PRTR which are LPS such as ports or extractive activities.

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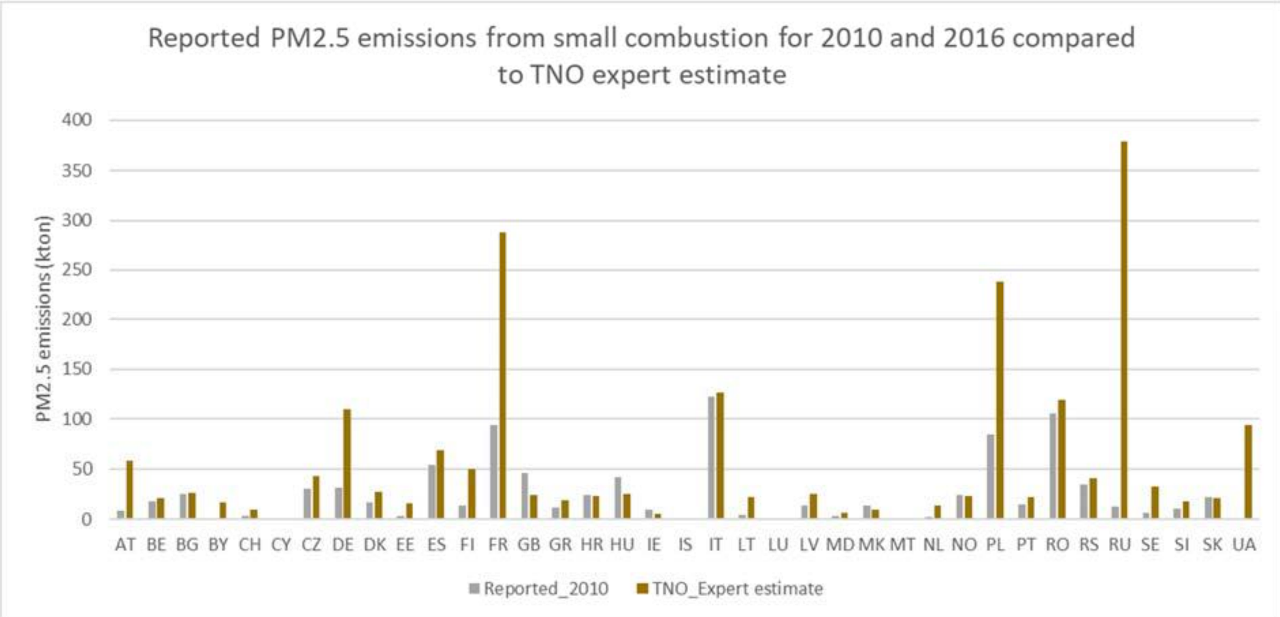
APPENDIX 1 SUMMARY INFORMATION ON CONDENSABLE IN PM

In order to improve atmospheric modelling and support the design of efficient and relevant policy for reducing the levels of air pollutants, emission inventory data need to be complete, accurate and comparable. With this aim, Italy immediately accepted the EMEP proposal on the necessity of accounting for condensable in PM emissions and generally applies these emission factors to all the categories. Of course, for certain categories is not possible to define if the emission factors includes condensable or not, as reported also in the 2019 Guidebook EMEP/EEA, consequently it is hard to fill the following table at category level but it is possible to provide more information. In particular, Italy uses emission factors with condensable for PM emissions from road transport thanks to the Copert model and in domestic and residential heating thanks several studies carried on in the last years about heating appliances, burning wood or other fuels. In particular, as concerns emissions from small combustion, a paper discussed during the 2019 meeting of TFEIP reported some independent verification on these estimates and Italy resulted in a good comparability with estimates of TNO (see Figure A1 1).

Figure A1 1 Comparison between TNO and countries estimates.



APPENDIX 2 UNCERTAINTY ASSESSMENT

In the following table detailed results, concerning NOx emissions, are reported for 2021 and for the trend (data submitted in 2023). In table A2.2 results for SOx 2022 emissions and in table A2.3 2023 results for CO emissions have been reported

Table A2.1 Results of the uncertainty analysis (Approach 1) for NOx. 2021 and trend assessment.

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Energy	1A1a - Public electricity and heat production	NOx	408.63	25.06	10.0	10.0	14.1	0.337	-93.9	0.6
Energy	1A1b - Petroleum refining	NOx	37.26	7.97	10.0	10.0	14.1	0.034	-78.6	0.0
Energy	1A1c - Manufacture of solid fuels and other energy industries	NOx	8.59	2.17	10.0	10.0	14.1	0.003	-74.8	0.0
Energy	1A2a - Stationary combustion in manufacturing industries and construction: Iron and steel	NOx	21.51	6.30	10.0	10.0	14.1	0.021	-70.7	0.0
Energy	1A2b - Stationary combustion in manufacturing industries and construction: Non-ferrous metals	NOx	2.85	0.82	10.0	10.0	14.1	0.000	-71.4	0.0
Energy	1A2c - Stationary combustion in manufacturing industries and construction: Chemicals	NOx	55.87	2.95	10.0	10.0	14.1	0.005	-94.7	0.1
Energy	1A2d - Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	NOx	2.84	4.42	10.0	10.0	14.1	0.010	55.4	0.0
Energy	1A2e - Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	NOx	11.13	1.77	10.0	10.0	14.1	0.002	-84.1	0.0
Energy	1A2f - Stationary combustion in manufacturing industries and construction: Non-metallic minerals	NOx	120.64	31.70	10.0	10.0	14.1	0.539	-73.7	0.0
Energy	1A2gvii - Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	NOx	30.76	4.54	20.0	20.0	28.3	0.044	-85.2	0.1
Energy	1A2gviii - Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	NOx	35.79	1.66	10.0	10.0	14.1	0.001	-95.4	0.1
Energy	1A3ai(i) - International aviation LTO (civil)	NOx	1.60	2.33	3.0	10.0	10.4	0.002	45.3	0.0

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Energy	1A3aii(i) - Domestic aviation LTO (civil)	NOx	1.36	1.59	3.0	10.0	10.4	0.001	17.0	0.0
Energy	1A3bi - Road transport: Passenger cars	NOx	590.92	128.06	3.0	10.0	10.4	4.793	-78.3	0.2
Energy	1A3bii - Road transport: Light duty vehicles	NOx	60.60	43.76	3.0	10.0	10.4	0.560	-27.8	0.1
Energy	1A3biii - Road transport: Heavy duty vehicles and buses	NOx	340.33	79.65	3.0	10.0	10.4	1.854	-76.6	0.1
Energy	1A3biv - Road transport: Mopeds & motorcycles	NOx	4.29	2.83	3.0	10.0	10.4	0.002	-34.1	0.0
Energy	1A3c - Railways	NOx	10.27	1.48	3.0	20.0	20.2	0.002	-85.5	0.0
Energy	1A3dii - National navigation (shipping)	NOx	95.55	78.89	2.0	10.0	10.2	1.735	-17.4	0.2
Energy	1A3ei - Pipeline transport	NOx	2.89	0.57	3.0	10.0	10.4	0.000	-80.4	0.0
Energy	1A4ai - Commercial/institutional: Stationary	NOx	11.26	30.85	10.0	10.0	14.1	0.510	173.9	0.2
Energy	1A4bi - Residential: Stationary	NOx	51.53	41.27	10.0	10.0	14.1	0.914	-19.9	0.2
Energy	1A4bii - Residential: Household and gardening (mobile)	NOx	0.02	0.00	10.0	10.0	14.1	0.000	-93.9	0.0
Energy	1A4ci - Agriculture/Forestry/Fishing: Stationary	NOx	0.97	12.94	10.0	20.0	22.4	0.224	1238.9	0.1
Energy	1A4cii - Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	NOx	102.39	23.70	10.0	20.0	22.4	0.753	-76.8	0.1
Energy	1A4ciii - Agriculture/Forestry/Fishing: National fishing	NOx	8.37	6.20	10.0	20.0	22.4	0.052	-25.9	0.0
Energy	1A5b - Other, Mobile (including military, land based and recreational boats)	NOx	11.16	1.70	3.0	50.0	50.1	0.019	-84.8	0.0
Energy	1B2aiv - Fugitive emissions oil: Refining / storage	NOx	5.00	5.33	3.0	20.0	20.2	0.031	6.7	0.0
Energy	1B2c - Venting and flaring (oil, gas, combined oil and gas)	NOx	0.27	0.19	3.0	20.0	20.2	0.000	-29.1	0.0
IPPU	2B1 - Ammonia production	NOx	1.46	0.22	3.0	10.0	10.4	0.000	-84.8	0.0
IPPU	2B2 - Nitric acid production	NOx	3.46	0.27	3.0	10.0	10.4	0.000	-92.3	0.0
IPPU	2B3 - Adipic acid production	NOx	0.02	0.02	3.0	10.0	10.4	0.000	42.8	0.0
IPPU	2B6 - Titanium dioxide production	NOx	0.05	0.04	3.0	10.0	10.4	0.000	-27.9	0.0
IPPU	2B7 - Soda ash production	NOx	0.09	0.14	3.0	10.0	10.4	0.000	58.5	0.0
IPPU	2B10a - Chemical industry: Other (please specify in the IIR)	NOx	16.97	1.78	3.0	10.0	10.4	0.001	-89.5	0.0

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
IPPU	2C1 - Iron and steel production	NOx	2.25	2.59	3.0	10.0	10.4	0.002	15.2	0.0
IPPU	2C2 - Ferroalloys production	NOx	0.01	0.00	3.0	10.0	10.4	0.000	-100.0	0.0
IPPU	2C3 - Aluminium production	NOx	0.50	0.00	3.0	10.0	10.4	0.000	-100.0	0.0
IPPU	2G - Other product use (please specify in the IIR)	NOx	0.17	0.13	5.0	30.0	30.4	0.000	-25.2	0.0
IPPU	2H1 - Pulp and paper industry	NOx	0.08	0.00	10.0	20.0	22.4	0.000	-100.0	0.0
AFOLU	3B1a - Manure management - Dairy cattle	NOx	0.75	0.36	5.0	20.0	20.6	0.000	-51.8	0.0
AFOLU	3B1b - Manure management - Non-dairy cattle	NOx	0.58	0.52	5.0	20.0	20.6	0.000	-11.3	0.0
AFOLU	3B2 - Manure management - Sheep	NOx	0.17	0.13	5.0	20.0	20.6	0.000	-23.0	0.0
AFOLU	3B3 - Manure management - Swine	NOx	0.02	0.02	5.0	20.0	20.6	0.000	2.7	0.0
AFOLU	3B4a - Manure management - Buffalo	NOx	0.03	0.06	5.0	20.0	20.6	0.000	118.9	0.0
AFOLU	3B4d - Manure management - Goats	NOx	0.02	0.02	5.0	20.0	20.6	0.000	-15.7	0.0
AFOLU	3B4e - Manure management - Horses	NOx	0.03	0.04	5.0	20.0	20.6	0.000	27.7	0.0
AFOLU	3B4f - Manure management - Mules and asses	NOx	0.01	0.01	5.0	20.0	20.6	0.000	-13.6	0.0
AFOLU	3B4gi - Manure mangement - Laying hens	NOx	0.00	0.14	5.0	20.0	20.6	0.000	5711.1	0.0
AFOLU	3B4gii - Manure mangement - Broilers	NOx	0.15	0.16	5.0	20.0	20.6	0.000	8.7	0.0
AFOLU	3B4giii - Manure mangement - Turkeys	NOx	0.09	0.06	5.0	20.0	20.6	0.000	-32.7	0.0
AFOLU	3B4giv - Manure management - Other poultry	NOx	0.02	0.03	5.0	20.0	20.6	0.000	63.2	0.0
AFOLU	3B4h - Manure management - Other animals (please specify in IIR)	NOx	0.10	0.07	5.0	20.0	20.6	0.000	-31.9	0.0
AFOLU	3Da1 - Inorganic N-fertilizers (includes also urea application)	NOx	30.38	21.56	20.0	20.0	28.3	0.997	-29.0	0.2
AFOLU	3Da2a - Animal manure applied to soils	NOx	20.93	18.64	20.0	50.0	53.9	2.701	-11.0	0.3
AFOLU	3Da2b - Sewage sludge applied to soils	NOx	0.20	0.30	20.0	50.0	53.9	0.001	49.7	0.0
AFOLU	3Da2c - Other organic fertilisers applied to soils	NOx	0.66	4.40	20.0	50.0	53.9	0.151	566.5	0.1
AFOLU	3Da3 - Urine and dung deposited by grazing animals	NOx	7.07	5.70	20.0	50.0	53.9	0.253	-19.3	0.1
Waste	3F - Field burning of agricultural residues	NOx	0.45	0.47	30.0	50.0	58.3	0.002	3.9	0.0
Waste	5C1a - Municipal waste incineration	NOx	0.46	0.00	10.0	20.0	22.4	0.000	-100.0	0.0
Waste	5C1bi - Industrial waste incineration	NOx	0.43	0.05	10.0	20.0	22.4	0.000	-88.4	0.0
Waste	5C1bii - Hazardous waste incineration	NOx	0.00	0.00	10.0	20.0	22.4	0.000	-100.0	0.0
Waste	5C1biii - Clinical waste incineration	NOx	0.07	0.03	10.0	20.0	22.4	0.000	-61.3	0.0

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Waste	5C1bv - Cremation	NOx	0.06	0.06	10.0	20.0	22.4	0.000	-5.6	0.0
Waste	5C2 - Open burning of waste	NOx	0.01	0.13	10.0	20.0	22.4	0.000	2342.9	0.0
TOTAL			**2124.05**	**610.69**			**4.1**		**-71.2**	**0.9**

Table A2.2 Results of the uncertainty analysis (Approach 1) for SOx. 2022 and trend assessment.

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Energy	1A1a - Public electricity and heat production	SOx	769.28	6.93	10.0	10.0	14.1	1.235	-99.1	0.2
Energy	1A1b - Petroleum refining	SOx	192.21	5.44	10.0	10.0	14.1	0.761	-97.2	0.0
Energy	1A1c - Manufacture of solid fuels and other energy industries	SOx	39.28	1.29	10.0	10.0	14.1	0.043	-96.7	0.0
Energy	1A2a - Stationary combustion in manufacturing industries and construction: Iron and steel	SOx	20.79	3.17	10.0	10.0	14.1	0.259	-84.7	0.0
Energy	1A2b - Stationary combustion in manufacturing industries and construction: Non-ferrous metals	SOx	15.07	1.25	10.0	10.0	14.1	0.041	-91.7	0.0
Energy	1A2c - Stationary combustion in manufacturing industries and construction: Chemicals	SOx	129.09	0.30	10.0	10.0	14.1	0.002	-99.8	0.0

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Energy	1A2d - Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	SOx	4.37	0.04	10.0	10.0	14.1	0.000	-99.0	0.0
Energy	1A2e - Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	SOx	25.47	0.03	10.0	10.0	14.1	0.000	-99.9	0.0
Energy	1A2f - Stationary combustion in manufacturing industries and construction: Non-metallic minerals	SOx	63.55	23.26	10.0	10.0	14.1	13.930	-63.4	0.2
Energy	1A2gvii - Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	SOx	3.50	0.01	20.0	20.0	28.3	0.000	-99.8	0.0
Energy	1A2gviii - Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	SOx	65.75	0.41	10.0	10.0	14.1	0.004	-99.4	0.0
Energy	1A3ai(i) - International aviation LTO (civil)	SOx	0.13	0.30	3.0	5.0	5.8	0.000	131.5	0.0
Energy	1A3aii(i) - Domestic aviation LTO (civil)	SOx	0.11	0.18	3.0	5.0	5.8	0.000	58.2	0.0
Energy	1A3bi - Road transport: Passenger cars	SOx	61.39	0.24	3.0	5.0	5.8	0.000	-99.6	0.0
Energy	1A3bii - Road transport: Light duty vehicles	SOx	15.97	0.05	3.0	5.0	5.8	0.000	-99.7	0.0
Energy	1A3biii - Road transport: Heavy duty vehicles and buses	SOx	49.64	0.11	3.0	5.0	5.8	0.000	-99.8	0.0
Energy	1A3biv - Road transport: Mopeds & motorcycles	SOx	2.29	0.01	3.0	5.0	5.8	0.000	-99.7	0.0
Energy	1A3c - Railways	SOx	1.18	0.00	3.0	5.0	5.8	0.000	-100.0	0.0
Energy	1A3dii - National navigation (shipping)	SOx	77.94	10.91	2.0	5.0	5.4	0.444	-86.0	0.0
Energy	1A3ei - Pipeline transport	SOx	0.01	0.01	3.0	5.0	5.8	0.000	-18.5	0.0
Energy	1A4ai - Commercial/institutional: Stationary	SOx	2.47	4.11	10.0	5.0	11.2	0.272	66.0	0.0
Energy	1A4bi - Residential: Stationary	SOx	72.87	5.08	10.0	5.0	11.2	0.414	-93.0	0.0
Energy	1A4bii - Residential: Household and gardening (mobile)	SOx	0.03	0.00	10.0	5.0	11.2	0.000	-100.0	0.0
Energy	1A4ci - Agriculture/Forestry/Fishing: Stationary	SOx	6.92	0.03	10.0	10.0	14.1	0.000	-99.6	0.0
Energy	1A4cii - Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	SOx	13.00	0.03	10.0	10.0	14.1	0.000	-99.8	0.0

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Energy	1A4ciii - Agriculture/Forestry/Fishing: National fishing	SOx	1.18	0.00	10.0	10.0	14.1	0.000	-99.8	0.0
Energy	1A5b - Other, Mobile (including military, land based and recreational boats)	SOx	1.19	0.16	3.0	50.0	50.1	0.008	-86.7	0.0
Energy	1B2aiv - Fugitive emissions oil: Refining / storage	SOx	67.40	14.14	3.0	20.0	20.2	10.531	-79.0	0.1
Energy	1B2c - Venting and flaring (oil, gas, combined oil and gas)	SOx	12.32	3.72	3.0	20.0	20.2	0.728	-69.8	0.0
IPPU	2B1 - Ammonia production	SOx	0.06	0.00	3.0	10.0	10.4	0.000	-93.3	0.0
IPPU	2B6 - Titanium dioxide production	SOx	2.60	0.14	3.0	10.0	10.4	0.000	-94.7	0.0
IPPU	2B7 - Soda ash production	SOx	0.12	0.15	3.0	10.0	10.4	0.000	22.0	0.0
IPPU	2B10a - Chemical industry: Other (please specify in the IIR)	SOx	58.36	5.20	3.0	10.0	10.4	0.380	-91.1	0.0
IPPU	2C1 - Iron and steel production	SOx	2.89	1.23	3.0	10.0	10.4	0.021	-57.3	0.0
IPPU	2C2 - Ferroalloys production	SOx	0.01	0.00	3.0	10.0	10.4	0.000	-100.0	0.0
IPPU	2C3 - Aluminium production	SOx	3.50	0.00	3.0	10.0	10.4	0.000	-100.0	0.0
IPPU	2G - Other product use (please specify in the IIR)	SOx	0.01	0.02	5.0	30.0	30.4	0.000	148.0	0.0
IPPU	2H1 - Pulp and paper industry	SOx	1.04	0.00	10.0	20.0	22.4	0.000	-100.0	0.0
AFOLU	3F - Field burning of agricultural residues	SOx	0.08	0.05	30.0	50.0	58.3	0.001	-39.6	0.0
Waste	5C1a - Municipal waste incineration	SOx	0.16	0.00	10.0	20.0	22.4	0.000	-100.0	0.0
Waste	5C1bi - Industrial waste incineration	SOx	0.28	0.05	10.0	20.0	22.4	0.000	-81.4	0.0
Waste	5C1bii - Hazardous waste incineration	SOx	0.00	0.00	10.0	20.0	22.4	0.000	-100.0	0.0
Waste	5C1biii - Clinical waste incineration	SOx	0.00	0.00	10.0	20.0	22.4	0.000	-53.7	0.0
Waste	5C1biv - Sewage sludge incineration	SOx	0.04	0.04	10.0	20.0	22.4	0.000	-6.1	0.0
Waste	5C1bv - Cremation	SOx	0.00	0.00	10.0	20.0	22.4	0.000	269.5	0.0
Waste	5C2 - Open burning of waste	SOx	0.07	0.07	30.0	50.0	58.3	0.002	-1.5	0.0
TOTAL			**1,783.60**	**88.15**			**5.4**			**0.3**

Table A2.3 Results of the uncertainty analysis (Approach 1) for CO. 2023 and trend assessment.

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Energy	1A1aPublic electricity and heat production	CO	22.12	16.31	10.0	10.0	10.0	10.0	14.1	
Energy	1A1bPetroleum refining	CO	2.81	3.13	10.0	10.0	10.0	10.0	14.1	
Energy	1A1cManufacture of solid fuels and other energy industries	CO	32.67	6.70	10.0	10.0	10.0	10.0	14.1	
Energy	1A2aStationary combustion in manufacturing industries and construction: Iron and steel	CO	232.29	50.41	10.0	10.0	10.0	10.0	14.1	
Energy	1A2bStationary combustion in manufacturing industries and construction: Non-ferrous metals	CO	17.85	6.80	10.0	10.0	10.0	10.0	14.1	
Energy	1A2cStationary combustion in manufacturing industries and construction: Chemicals	CO	6.95	1.73	10.0	10.0	10.0	10.0	14.1	
Energy	1A2dStationary combustion in manufacturing industries and construction: Pulp, Paper and Print	CO	0.00	0.00	10.0	10.0	10.0	10.0	14.1	
Energy	1A2eStationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	CO	0.82	1.22	10.0	10.0	10.0	10.0	14.1	
Energy	1A2fStationary combustion in manufacturing industries and construction: Non-metallic minerals	CO	44.73	21.95	10.0	10.0	10.0	10.0	14.1	
Energy	1A2gvii Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	CO	9.94	6.02	20.0	20.0	20.0	20.0	28.3	
Energy	1A2gviiiStationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	CO	2.94	2.38	10.0	10.0	10.0	10.0	14.1	
Energy	1A3ai(i)International aviation LTO (civil)	CO	1.73	3.28	3.0	3.0	10.0	10.0	10.4	
Energy	1A3aii(i)Domestic aviation LTO (civil)	CO	1.23	1.67	3.0	3.0	10.0	10.0	10.4	
Energy	1A3biRoad transport: Passenger cars	CO	4,124.63	162.23	3.0	3.0	10.0	10.0	10.4	
Energy	1A3biiRoad transport: Light duty vehicles	CO	175.06	6.73	3.0	3.0	10.0	10.0	10.4	
Energy	1A3biiiRoad transport: Heavy duty vehicles and buses	CO	81.44	25.29	3.0	3.0	10.0	10.0	10.4	
Energy	1A3bivRoad transport: Mopeds & motorcycles	CO	493.42	80.43	3.0	3.0	10.0	10.0	10.4	

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Energy	1A3cRailways	CO	2.10	0.13	3.0	3.0	20.0	20.0	20.2	
Energy	1A3diiNational navigation (shipping)	CO	102.27	40.14	2.0	2.0	10.0	10.0	10.2	
Energy	1A3eiPipeline transport	CO	1.26	0.33	3.0	3.0	10.0	10.0	10.4	
Energy	1A4aiCommercial/institutional: Stationary	CO	7.56	25.80	10.0	10.0	10.0	10.0	14.1	
Energy	1A4biResidential: Stationary	CO	787.23	1,171.42	10.0	10.0	10.0	10.0	14.1	
Energy	1A4biiResidential: Household and gardening (mobile)	CO	17.16	0.54	10.0	10.0	10.0	10.0	14.1	
Energy	1A4ciAgriculture/Forestry/Fishing: Stationary	CO	0.35	10.73	10.0	10.0	20.0	20.0	22.4	
Energy	1A4ciiAgriculture/Forestry/Fishing: Off-road vehicles and other machinery	CO	278.75	31.83	10.0	10.0	20.0	20.0	22.4	
Energy	1A4ciiiAgriculture/Forestry/Fishing: National fishing	CO	2.15	1.46	10.0	10.0	20.0	20.0	22.4	
Energy	1A5bOther, Mobile (including military, land based and recreational boats)	CO	65.12	14.60	3.0	3.0	50.0	50.0	50.1	
Energy	1B2aivFugitive emissions oil: Refining / storage	CO	8.77	0.07	3.0	3.0	20.0	20.0	20.2	
IPPU	2B1Ammonia production	CO	0.29	0.05	3.0	3.0	10.0	10.0	10.4	
IPPU	2B7Soda ash production	CO	9.15	5.95	3.0	3.0	10.0	10.0	10.4	
IPPU	2B10a Chemical industry: Other (please specify in the IIR)	CO	15.04	13.42	3.0	3.0	10.0	10.0	10.4	
IPPU	2C1Iron and steel production	CO	158.71	37.40	3.0	3.0	10.0	10.0	10.4	
IPPU	2C2Ferroalloys production	CO	0.34	0.00	3.0	3.0	10.0	10.0	10.4	
IPPU	2C3Aluminium production	CO	31.39	0.00	3.0	3.0	10.0	10.0	10.4	
IPPU	2D3cAsphalt roofing	CO	0.01	0.01	5.0	5.0	30.0	30.0	30.4	
IPPU	2G Other product use (please specify in the IIR)	CO	5.12	4.12	5.0	5.0	30.0	30.0	30.4	
AFOLU	3FField burning of agricultural residues	CO	18.49	14.24	30.0	30.0	50.0	50.0	58.3	
Waste	5C1aMunicipal waste incineration	CO	0.03	0.00	10.0	10.0	20.0	20.0	22.4	
Waste	5C1biIndustrial waste incineration	CO	0.12	0.02	10.0	10.0	20.0	20.0	22.4	
Waste	5C1biiHazardous waste incineration	CO	0.00	0.00	10.0	10.0	20.0	20.0	22.4	
Waste	5C1biiiClinical waste incineration	CO	0.01	0.00	10.0	10.0	20.0	20.0	22.4	
Waste	5C1bivSewage sludge incineration	CO	0.01	0.01	10.0	10.0	20.0	20.0	22.4	
Waste	5C1bvCremation	CO	0.00	0.00	10.0	10.0	20.0	20.0	22.4	

Inventory sector	Category code and name	Gas	Base year emissions	Year t emissions	Activity data uncertainty	Emission factor /estimation parameter uncertainty	Combined uncertainty	Contribution to variance by category in year t	Inventory trend in national emissions for year t increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year
					%	%	%	(fraction)	(% of base year)	%
Waste	5C2Open burning of waste	CO	61.52	80.62	30.0	30.0	50.0	50.0	58.3	
TOTAL			**6823.58**	**1849.16**			**9.4**			**2.5**

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