ITALIAN EMISSION INVENTORY 1990 - 2019

INFORMATIVE INVENTORY REPORT 2021

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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 up to the year 2019, 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 is in charge of 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, and various heavy metals and POPs. The submission consists of the national emission inventory, communicated through compilation of the Nomenclature Reporting Format (NRF), and the informative inventory report (IIR) to ensure the properties of transparency, consistency, comparability, completeness and accuracy.

In the period 1990-2019, emissions from almost all the pollutants described in this report show a downward trend. Reductions are especially relevant for the main pollutants (SO_X -94%; NO_X -71%; CO -70%; NMVOC -55%), for BC (-62%), cadmium (-60%), mercury (-57%), lead (-95%) and hexachlorobenzene (-93%). 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 88%; NO_X 91%; CO 94%; PM2.5 88%; BC 94%; PAH 84%). 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 cement production and 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 94% in national total. Finally, the waste sector, specifically waste incineration, is a relevant source for Cd (12%).

Emission figures of the Italian emission inventory and other related documents are publicly available at http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni.

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 the human health and the environment through the intergovernmental cooperation.

The fact that air pollutants could travel several thousands of kilometres 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 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	

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 has to 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 Reporting Format* (NRF), and the *Informative Inventory Report* (IIR).

The Italian informative inventory report contains information on the national inventory for the year 2018, 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 2019 are reported in Table 1.2.

Table 1.2 *Emission time series by pollutant*

		1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
SOx	*Gg*	1,784	1,322	756	411	222	127	119	117	109	105
NOx	*Gg*	2,125	1,989	1,504	1,289	934	719	699	646	639	627
NMVOC	*Gg*	1,994	2,059	1,630	1,340	1,117	901	884	925	897	894
NH3	*Gg*	467	452	454	419	377	364	377	371	358	355
CO	*Gg*	6,797	7,072	4,751	3,467	3,073	2,271	2,195	2,261	2,052	2,062
As	*Mg*	37	28	39	28	17	9	9	8	8	7
Cd	*Mg*	11	11	10	9	5	4	5	5	5	4
Cr	*Mg*	86	69	44	50	40	35	35	35	35	34

		1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Cu	*Mg*	193	216	222	230	203	189	180	171	173	171
Hg	*Mg*	15	14	14	12	8	7	7	7	7	6
Ni	*Mg*	114	110	107	112	41	30	30	30	30	28
Pb	*Mg*	4,280	1,996	964	298	218	199	203	206	205	199
Se	*Mg*	8	8	8	9	8	8	7	7	7	7
Zn	*Mg*	948	952	906	981	877	815	832	874	887	851
TSP	*Gg*	350	346	303	275	287	237	231	239	218	215
PM10	*Gg*	293	288	248	223	234	191	186	193	174	172
PM2.5	*Gg*	227	225	195	173	196	158	153	160	142	139
BC	*Gg*	47	46	42	38	32	22	21	21	19	18
PAH	*Mg*	90	92	60	64	87	71	70	74	67	65
Dioxin	*g ITeq*	503	485	408	334	318	281	280	296	277	271
HCB	*kg*	139	107	28	22	12	12	11	11	10	10
PCB	*kg*	152	163	152	174	128	109	114	117	116	112

The NRF files and other related documents can be found on website at the following address: http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni.

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 for the Environment, Land and Sea 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 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 Energy Balance (annual), Petrochemical Bulletin (quarterly publication), by MSE (Ministry of Economic Development);
- Transport Statistics Yearbooks, by MIT (Ministry of Transportation);
- Annual Statistics on Electrical Energy in Italy, by TERNA (National Independent System Operator);
- Annual Report on Waste, by ISPRA;
- National Forestry Inventory, by MIPAAF (Ministry of Agriculture, Food and Forest Policies).

The national emission inventory itself is a Sistan product (ISPRA).

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 improving 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 researches 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 Economic Development (MSE) 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 NRF 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 http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni.

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*

SECTOR	ACTIVITY DATA	SOURCE
1 Energy 1A1 Energy Industries	Fuel use	Energy Balance - Ministry of Economic Development Major national electricity producers European Emissions Trading Scheme
1A2 Manufacturing Industries and Construction	Fuel use	Energy Balance - Ministry of Economic Development Major National Industry Corporation European Emissions Trading Scheme
1A3 Transport	Fuel use Number of vehicles Aircraft landing and take-off cycles and maritime activities	Energy Balance - Ministry of Economic Development 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 - Ministry of Economic Development
1B Fugitive Emissions from Fuel	Amount of fuel treated, stored, distributed	Energy Balance - Ministry of Economic Development Statistical Yearbooks - Ministry of Transportation Major National Industry Corporation
2 Industrial Processes	Production data	National Statistical Yearbooks- National Institute of Statistics International Statistical Yearbooks-UN European Emissions Trading Scheme European Pollutant Release and Transfer Register Sectoral Industrial Associations
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 and Forestry	Forest and soil surfaces Amount of biomass Biomass burnt Biomass growth	Statistical Yearbooks - National Institute of Statistics State Forestry Corps National and Regional Forestry Inventory 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; 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 Report*, submitted in the framework of the UN *Convention on Climate Change* and the *Kyoto Protocol* (ISPRA, 2021 [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 Economic Development. 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. 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 for the Environment, Land and Sea and to the European Commission within 31st March of the current year for data referring to two years earlier. 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.

In case 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 by 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, 2019). 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 National Format Report; 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 2019 (Table 1.5) by pollutant.

The trend analysis has also been applied considering 1990 and 2019. 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%)	1A2gvii i (3.7%)	1A3b i (3.4%)						80.5
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	3Da2a (20.8%)	3B1a (19.9%)	3B1b (19.0%)	3Da1 (14.9%)	3B3 (7.9%)									82.5
NMVOC	1A3b i (21.6%)	2D3d (13.6%)	1A3b iv (8.8%)	1A3b v (6.0%)	2D3a (5.8%)	1A4b i (5.0%)	2D3g (3.9%)	1A4c ii (3.5%)	2D3i (3.3%)	1B2a v (3.0%)	2D3e (2.6%)	3B1a (2.5%)	3B1b (2.3%)	81.9
CO	1A3b i (60.7%)	1A4b i (11.6%)	1A3b iv (7.3%)	1A4c ii (4.1%)										83.6
PM10	1A4b i (23.0%)	1A1a (12.9%)	1A3b i (6.6%)	1A4c ii (5.5%)	1A3b iii (4.6%)	3Dc (4.3%)	1A3b ii (3.5%)	1A2f (3.5%)	1A3d ii (3.2%)	3B4g ii (2.8%)	1A3b vi (2.6%)	2C1 (2.5%)	2A1 (2.4%)	
	1A2a (2.2%)	1A2c (1.9%)												81.4
PM2.5	1A4b i (29.2%)	1A1a (11.1%)	1A3b i (8.5%)	1A4c ii (7.0%)	1A3b iii (6.0%)	1A3b ii (4.6%)	1A3d ii (4.1%)	1A2f (3.4%)	2C1 (2.6%)	1A2a (2.2%)	1A3bvi (1.8%)			80.4
BC	1A3b i (21.9%)	1A4c ii (19.0%)	1A3b iii (14.3%)	1A3b ii (12.0%)	1A4b i (11.0%)	1A2g vii (4.9%)								83.1
Pb	1A3b i	1A3b iv												83.0

Table 1.5 *Key categories for the Italian Emission Inventory in 2019*

	Key categories in 2019													Total (%)
SO_x	1A3d ii (23.8%)	1A2f (15.4%)	1B2a iv (12.7%)	1A1a (6.4%)	1A2a (6.3%)	2A1 (5.5%)	1A4b i (5.4%)	2B10a (4.7%)						80.2
NO_x	1A3b i (20.3%)	1A3d ii (13.2%)	1A3b iii (13.0%)	1A3b ii (6.6%)	1A4b i (6.3%)	1A4a i (5.5%)	1A2f (5.2%)	1A4c ii (4.5%)	1A1a (4.3%)	3Da1 (3.0)				81.7
NH_3	3B1b (19.7%)	3Da2a (18.5%)	3B1a (15.5%)	3Da1 (14.2%)	3B3 (8.8%)	3B4g ii (3.6%)								80.4
NMVOC	2D3d (17.3%)	1A4b i (15.8%)	2D3a (10.2%)	2D3g (5.7%)	1A3b v (4.8%)	3B1b (4.4%)	3B1a (4.2%)	1A3b iv (3.6%)	1A4a i (3.4%)	2D3 i (3.1%)	2H2 (2.7%)	1A3b i (2.6%)	1B2b (2.1%)	
	2D3h (1.9%)													81.6
CO	1A4b i (59.6%)	1A3b i (12.0%)	1A3b iv (5.1%)	1A2a (3.9%)										80.6
PM10	1A4b i (53.5%)	3Dc (6.0%)	1A3b vi (4.9%)	1A3d ii (3.6%)	1A2f (2.8%)	2C1 (2.8%)	1A3bvii (2.6%)	1A3b i (2.3%)	2A1 (2.1%)					80.6
PM2.5	1A4b i (65.3%)	1A3d ii (4.5%)	1A3b vi (3.3%)	1A2f (3.0%)	1A3b i (2.8%)	2C1 (2.8%)								81.8
BC	1A4b i (45.4%)	1A3b i (16.8%)	1A3d ii (5.9%)	1A3b iii (5.8%)	5C2 (4.8%)	1A4c ii (4.5%)								83.2
Pb	2C1	1A2f	1A2a	1A3b vi										83.4

Table 1.6 *Key categories for the Italian Emission Inventory in trend 1990-2019*

	Key categories in trend													Total (%)
SO_X	1A1a (29.1%)	1A3d ii (15.4%)	1A2f (10.3%)	1B2a iv (7.1%)	1A2c (5.2%)	1A1b (4.9%)	1A2a (4.1%)	2A1 (3.4%)	1A4a i (3.1%)					82.8
NO_X	1A1a (23.4%)	1A3dii (13.6%)	1A3b i (11.8%)	1A4a i (7.7%)	1A4b i (6.1%)	1A3b ii (5.8%)	1A3b iii (4.8%)	1A4c i (3.0%)	3Da2a (3.0%)	1A2c (3.0%)				82.2
NH_3	3B1a (22.8%)	3Da2a (11.6%)	3Da2c (8.3%)	3B4a (7.4%)	1A3b i (5.9%)	3B4g i (5.2%)	3B4g ii (5.0%)	1B2d (5.0%)	3B3 (4.9%)	5B2 (3.9%)				80.1
NMVOC	1A3b i (26.4%)	1A4b i (15.0%)	1A3b iv (7.2%)	2D3a (6.0%)	2D3d (5.1%)	1A4a i (4.4%)	1A4c ii (3.8%)	3B1b (2.8%)	2D3g (2.5%)	3B1a (2.4%)	1B2a v (2.0%)	2H2 (1.6%)	1A3b v (1.6%)	80.8
CO	1A3b i (43.2%)	1A4b i (42.6%)												85.9
PM10	1A4b i (36.9%)	1A1a (15.3%)	1A4c ii (5.6%)	1A3b i (5.2%)	1A3biii (4.5%)	1A3b ii (3.7%)	1A3b vi (2.7%)	1A2a (2.4%)	1A1b (2.2%)	3Dc (2.0%)				80.3
PM2.5	1A4b i (42.1%)	1A1a (12.7%)	1A4c ii (7.0%)	1A3b i (6.6%)	1A3b iii (5.7%)	1A3b ii (4.6%)	1A2a (2.4%)							81.0
BC	1A4b i (38.0%)	1A4c ii (16.0%)	1A3b iii (9.4%)	1A3b ii (9.3%)	1A3b i (5.7%)	1A2gvii (4.6%)								82.9
Pb	1A3b i (42.5%)	2C1 (18.6%)	1A2f (16.0%)	1A2a (4.8%)										81.9
Cd	1A2b	2C1	1A2a	1A2f	5C2	1A3b i	2G							84.1

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, 2021 [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 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.

Feedbacks 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 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 accountings, 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 for the Environment, Land and Sea 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). A summary of the main findings of the last review can be found in the relevant technical report at the address

http://www.ceip.at/fileadmin/inhalte/emep/pdf/2013_s3/ITALY-Stage3ReviewReport-2013.pdf.
Moreover, under the European National Emission Ceiling Directive (NECD), an in-depth review has been conducted in 2017, 2018, 2019 and in 2020 (EEA, 2017 [a]; EEA 2018; EEA 2019; EEA 2020). 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-2A1-2019-0001	Yes	2A1 Cement Production, PM2.5, 1990-2018	In the 2019 review, the TERT noted that for 2A1 Cement Production for $PM_{2.5}$ for 1990-2018 the $PM_{2.5}$ estimate was equal to the estimate for PM_{10}. In response to a question raised during the review about the calculations used, Italy explained that they have applied Tier 1 emission factors for cement production activity (2A1), equal to 234 g/t, 130 g/t and 3% of $PM_{2.5}$ respectively for PM_{10}, $PM_{2.5}$ and BC and that they have applied these EFs to cement production. However, these emission factors should be applied to clinker as indicated in the 2016 and 2019 EMEP/EEA Guidebook and therefore emissions are over-	RE	Implemented

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			estimated. Italy provided revised estimates for years 1990-2018 for PM_{10}, $PM_{2.5}$ and BC and stated that these will be included in the next submission. The TERT agreed with the revised estimate provided by Italy. The TERT recommends that Italy include the revised estimate in its 2021 NFR and IIR submission.		
IT-1A4ai-2017-0002	Yes	1A4ai Commercial/Institutional: Stationary, NMVOC, 2000-2015	For category 1A4ai Commercial/Institutional: Stationary the TERT noted that there is a lack of transparency regarding the emission factor references although some information has been added to the IIR. This does not relate to an over- or under-estimate of emissions. This was raised during the 2017, 2018 and 2019 NECD review. In response to a question raised during the review, Italy provided a summary of emission factors and references and explained that the few emission factors from older versions of the EMEP/EEA Guidebook were used in activities which were minor sources. Clearly for some years use of emission factors from older versions of the EMEP/EEA Guidebook will be appropriate however, the TERT recommends that Italy updates emission factors from older versions of the EMEP/EEA Guidebook in its inventory for current and recent years for the 2021 submission.	No	Implemented
IT-1A4bi-2017-0001	Yes	1A4bi Residential: Stationary, NO_X, NMVOC, PM2.5, 2000-2015	For category 1A4bi Residential: Stationary the TERT noted that there is a lack of transparency regarding the emission factor references although some information has been added to the IIR. In response to a question raised during the review, Italy provided a summary of emission factors and references and explained that the few emission factors from older versions of the EMEP/EEA Guidebook were used in activities which were minor sources. Clearly for some years use of emission factors from older versions of the EMEP/EEA Guidebook will be appropriate however, the TERT recommends that Italy updates emission factors from older versions of the EMEP/EEA Guidebook in its inventory for current and recent years for the 2021 submission.	No	Implemented
IT-2A5a-2017-0001	No	2A5a Quarrying and Mining of Minerals Other Than Coal, PM2.5, 1990-2018	For 2A5a Quarrying and Mining of Minerals Other Than Coal for PM2.5 emissions for 1990-2018 the TERT noted that there is a lack of transparency regarding the details of the rough estimate provided for 2017 and regarding the resulting total of 150 Mg of emissions and why no emissions for recycled aggregates are included while these relate to high EF. This does not relate to an over- or under-estimate of emissions. Italy explained that the calculations are made using the spreadsheet available in the 2019	No	Not fully implemented. Additional information has been included in the IIR

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			EMEP/EEA Guidebook (2.A.5.a Quarrying and mining calculation model 2019 - Spreadsheet.xlsx) introducing production data for 2015 (last year available) as reported in the USGS database for crushed rocks, sand and gravels without modifying the other default values introduced (e.g. the number of plants) because at the moment these are unknown. The results were made available in an Excel file. Italy also stated that most part of emissions are due to the internal transportation, mostly due to resuspension of particles which do not seem be included in the inventory (for road transport it is not). Italy plans to include the relevant country specific information for the next submission. Italy did not include emissions of recycled aggregates since crushed asphalt is recycled in specific plants and these emissions are already reported under the relevant category while for crushed concrete there are no specific information available in the USGS statistics and no other statistics are available to Italy's knowledge that could be used instead. The TERT recommends that Italy includes a clear explanation of the method, EF and emissions calculated in its next submission and that Italy includes the emissions from recycled concrete based on e.g. information about building stock/demolition data since with these recycled aggregates relevant emissions may occur		
IT-2A5b-2017-0001	No	2A5b Construction and Demolition, PM2.5, 1990-2018	For 2A5b Construction and Demolition and pollutant PM2.5 for the years 1990-2018 the TERT noted that there is a lack of transparency regarding the investigations that Italy plans to collect statistical data. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Italy explained that a study is under finalization estimating the land use change and relative loss of soils and that they intend to start from that work to estimate a reliable time series of construction activities in the country with the aim to apply a Tier 1 methodology. Alternatively, the evaluation of environmental permits for some construction work of national interest such as road or railway constructions could be studied, but the number of works is not representative of the national works. The TERT recommends that Italy reports on its further investigations in its next IIR and includes an estimate of emissions in its submission if feasible.	No	Not fully implemented. Additional information has been included in the IIR
IT-2D3e-2017-0001	No	2D3e Degreasing, NMVOC, 1990-2018	For 2D3e Degreasing, NMVOC emissions and for 1990-2018 the TERT noted (IIR p. 148) that no method and EF are used according to the 2016 EMEP/EEA Guidebook as recommended in earlier reviews. This was raised during the 2017, 2018 and 2019 NECD reviews. The 2020	No	Not fully implemented. Information on the amount of cleaning products is not yet available.

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			review noted that the IIR (p. 148) states also that the issue is being reviewed by Italy on how to apply the emission factors available in the EMEP/EEA Guidebook that refers to the volumes of cleaning products used instead of the solvent used. The TERT reiterates the recommendation that Italy reports in more detail on these investigations in its next submission.		
IT-2I-2019-0001	No	2I Wood Processing, TSP	For 2I Wood Processing for TSP for 1990-2018 the TERT noted that Italy included estimates in its submission, but this is not mentioned in the IIR methodological chapter. However, it is mentioned in the IIR (page 25) in the table 'Recommendations from TERT, considering revised estimates (RE) and technical corrections (TC)'. This was raised during the 2019 NECD review. The TERT recommends that Italy includes in its next IIR (2021) the method and EF used to estimate these emissions.	No	Implemented. Methodology and relevant information on activity data and emission factor has been reported in paragraph 4.2.4 of the IIR.
IT-3B-2019-0001	Yes	3B Manure Management, NO_X, NH_3, 2000-2017	For 3B Manure Management, NH_3 and NO_X emissions the TERT noted that there is a lack of transparency regarding the amount of different substrates treated in biogas facilities. This does not relate to an over- or under-estimate of emissions. This was raised during the 2019 NECD review. In response to a question raised during the review, Italy clarified that, following the 2019 TERT recommendation, annual quantities of livestock manures and the volatile solid content, expressed as kg/t feed of livestock manures, is provided in pages 166-167 of the IIR 2020. The TERT recommends that Italy also includes the amount of nitrogen treated by biogas facilities.	No	Implemented. Data on the amount of nitrogen from manure treated by biogas facilities have been reported in Table 6.9 of the Agriculture sector of the IIR
IT-3Df-2020-0001	Yes	3Df Use of Pesticides, HCB, 1990, 2005, 2016, 2017	For 3Df Use of pesticides, HCB and years 1990, 2005, 2016, 2017 the TERT noted that significant recalculations have been applied (>10% change) for the key category 3Df for the pollutant(s) HCB and year(s) (1990, 2005, 2016-2017). In response to a question raised during the review Italy provided revised estimates that the TERT disagreed with. The TERT decided to calculate a technical correction for the 1990, 2005, 2016, 2017 which was accepted by Italy. The estimates demonstrate that the issue is above the threshold of significance. The TERT recommends that Italy include a revised estimate in its next submission.	TC	Implemented
IT-1A2a-2019-0001	Yes	1A2a Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel, PCBs, Cd, HCB, 1990-2018	For category 1A2a Stationary Combustion in Manufacturing Industries and Construction: Iron and Steel and pollutants Cd and HCB the TERT noted that the IEF ratios are outliers when compared to other Member States. Italy provided a revised estimate for years 2003-2018 for Cd and stated that it will be included in the next submission. The TERT agreed with the revised estimate provided by Italy for	RE	Implemented for cadmium emissions

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			Cd and agreed no change for HCB. The TERT recommends that Italy include the revised estimate in its 2021 NFR and IIR submission and reviews the methodology for HCB emission estimates.		
IT-0A-2020-0002	No	0A National Total - National Total for the Entire Territory - Based on Fuel Sold/Fuel Used, SO_2, NO_X, NH_3, NMVOC, $PM_{2.5}$, BaP, PAHs, PCBs, HCB, Cd, Hg, Pb, PCDD/F, PM_{10}, CO, 2018	The TERT recommends that further information on the methods used to quantify uncertainties are presented in the IIR transparently in accordance with the “Recommended Structure for Informative Inventory Report”	No	Not implemented
IT-1A1-2019-0001	Yes	1A1 Energy Production, BaP, PAHs, PCBs, HCB, Cd, Hg, Pb, PCDD/F, 1990 - 2017	For category 1A1 Energy Production that there is a lack of transparency regarding the basis of emission factors used for heavy metals and POPs. Some issues are resolved by commentary provided in the 2020 IIR to cover heavy metals and POPs. This does not relate to an over- or under-estimate of emissions. In response to questions raised during the review, Italy explained that emission factors for heavy metals for 1A1a are country-specific factors and all are derived from a national study from 2001. PCB emission factors are from the 2019 EMEP/EEA Guidebook. PAH, PCDD/F and HCB emission factors are drawn from a TNO study from 1997. The TERT notes Italy's comment that the EMEP/EEA Guidebook emission factors often reference US sources and facilities for POPs and heavy metals, but the EMEP/EEA Guidebook factors are generally applicable. The TERT recommends that Italy improve the information provided in the IIR and, to review current emission factors and emission data against PRTR (where available) and against the EMEP/EEA Guidebook factors and other industry resources.	No	Not yet implemented. Additional information has been included in the IIR. A preliminary analysis of data availability for the time series and comparison with the actual EFs has been done.
IT-1A1c-2019-0001	No	1A1c Manufacture of Solid Fuels and Other Energy Industries, PAHs, 2005	For categories 1A1c Manufacture of Solid Fuels and Other Energy Industries and 1B1b Fugitive Emission from Solid Fuels: Solid Fuel Transformation and pollutant PAH, the TERT noted an over-estimate above the threshold of significance. In the 2019 review, Italy accepted a Potential Technical correction as a Revised Estimate. In the 2020 submission, Italy's IIR indicates that revised estimates have been incorporated into the 2020 submission for 1A1c and that the 1A1b Petroleum refining revised estimate has been incorporated into category 2C Metal production but this emission will be allocated to 1B1b in the next submission (IIR page 30). This was raised during the 2018 and 2019 NECD review. The 2020 review noted that the IIR states that the outstanding issue has been included in the list of improvements and	TC 2019	Implemented

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			that the recommendation will be addressed in the 2021 submission. The TERT reiterates the recommendation that PAH emissions are correctly allocated to category 1B1b.		
IT-1A2-2019-0001	Yes	1A2 Stationary Combustion in Manufacturing Industries and Construction, BaP, PAHs, PCBs, HCB, Cd, Hg, Pb, PCDD/F, 1990-2018	For category 1A2 Stationary Combustion in Manufacturing Industries and Construction there is a lack of transparency regarding the basis of emission factors used for heavy metals and POPs. . In response to questions raised during the review, Italy explained that emission factors are a mix of country-specific and default factors from various versions of the EMEP/EEA Guidebook. The TERT notes Italy's commentary on PRTR data and an intent to update default emission factors for key categories to those from the 2019 EMEP/EEA Guidebook. The TERT recommends that Italy improve the information provided in the IIR to reference the emission factors used and, to update emission factors from older versions of the EMEP/EEA Guidebook with current emission factors in time for the 2021 submission.	No	Not fully implemented. Additional information has been included in the IIR.
IT-1A2b-2019-0001	No	1A2b Stationary Combustion in Manufacturing Industries and Construction: Non-Ferrous Metals, HCB, 1990-2018	For category 1A2b Stationary Combustion in Manufacturing Industries and Construction: Non-Ferrous Metals and pollutant HCB, the TERT noted the use of notation key 'NA' in activity 1A2b which is not appropriate as solid fuel use is reported in the activity in several years and there is a Tier 1 emission factor in the 2016 EMEP/EEA Guidebook that can be applied. In response to a question raised during the review, Italy commented that a national study on dioxin emissions may also have data for HCB that could be applied. The TERT noted that the issue is below the threshold of significance for a technical correction. The TERT recommends that Italy reviews national data and the EMEP/EEA Guidebook for suitable emission factors and includes an estimate of HCB emissions for relevant years in the 2021 submission. However, Italy should also review reporting of emissions for metals activities, in particular use of notation keys and ensure allocation of emissions with the primary NFR activity in the 2021 submission	No	Not implemented
IT-1A2b-2019-0002	Yes	1A2b Stationary Combustion in Manufacturing Industries and Construction: Non-Ferrous Metals, PCDD/F, 1990-2018	The TERT recommends that Italy review reporting of emissions for metals activities, in particular use of notation keys and ensure allocation of emissions with the primary NFR activity (2C3) in the 2021 submission.	No	Implemented. Notation key IE has been reported in 2C3..
IT-2C3-2020-0001	No	2C3 Aluminium Production, $PM_{2.5}$, HCB, PCDD/F, PM_{10}, BC, 1990-2018	For 2C3 Aluminium Production for $PM_{2.5}$, HCB, PCDD/F, PM_{10}, BC for 1990-2018 the TERT noted that there is a lack of transparency regarding the allocation of the emissions. Emissions were reported as 'NO'	No	Not implemented. Notation key IE has been

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			while in the IIR it is mentioned (p. 81-82) that secondary aluminium production takes place. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Italy explained that in general it reports emission from secondary aluminium production in the energy sector (1A2b) and emission from primary aluminium production under 2C3 category. And that primary aluminium production stopped its activity in Italy in 2012 and therefore 'NO' is reported in 2C3. Emission from secondary aluminium, including PM and POPs from the process are reported in the energy sector. And that the emission factor of Dioxin and PAH are country specific while PM_{10} is from USEPA and the speciation of $PM_{2.5}$ and BC refer to the value reported in the EMEP/EEA Guidebook for secondary aluminium. Italy plans to check the completeness of these EFs, especially of PM_{10} for its next submission and if it is possible to report separately processes from combustion emissions. The TERT recommends that Italy reports the process emissions from 2C3 in this category in its next submission and clearly describes the method, AD and EF used and on the completeness of the emission factors.		reported when relevant.
IT-2D3a-2018-0001	No	2D3a Domestic Solvent Use Including Fungicides, Hg, 1990, 2005, 2016	For 2D3a Domestic Solvent Use Including Fungicides, Hg and all years the TERT noted that the notation key 'NE' is used in the 2020 submission of the NFR tables. The 2018 and 2019 NECD review had flagged that notation key 'NA' was used instead of actual reported emissions. The TERT noted that the issue is below the threshold of significance for a technical correction. The TERT recommends Italy to use the notation key 'NA' instead in its next submission as the 2019 EMEP/EEA Guidebook no longer contain an EF for Hg for 2D3a.	No	Implemented
IT-2G-2018-0002	Yes	2G Other Product Use, Cd, Pb, 1990-2018	For 2G Other Product Use for Cd and Pb for 1990-2018 the TERT noted that there is a lack of transparency regarding the implementation of the revised estimate proposed in 2019. The TERT recommends that Italy carries out these investigations and reports clearly about these in its next IIR and updates the emission estimate if needed.	RE 2019	Implemented. Additional information has been included in the IIR
IT-5C-2019-0001	Yes	5C Waste Incineration, PCBs, HCB, 1990-2018	For 5C Waste Incineration, PCBs, HCB and years 1990-2018 the TERT noted that there is a lack of transparency regarding the use and origin of the emission factors used. This does not relate to an over- or under-estimate of emissions. The TERT reiterates the recommendation from the 2019 review to take in account the implementation of abatement technology over the years for those sources where this is not considered yet (for instance 5C1bv). The TERT additionally, recommends Italy to further improve the transparency in the IIR and to use the emission factors from	No	Additional information has been included in the IIR while the improvement on incineration of sewage sludge is planned for 2022.

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			the survey on incineration of sewage sludge in the 2022 submission.		
IT-5C1a-2020-0001	No	5C1a Municipal Waste Incineration, SO_2, NO_X, NH_3, NMVOC, $PM_{2.5}$, BaP, PAHs, PCBs, HCB, Cd, Hg, Pb, PCDD/F, PM_{10}, CO, BC, 2013-2018	The TERT recommends that Italy continues to use 'NO' as notation key when all incineration is with energy recovery, to report the emissions from this in the energy sector and to correct the data in IIR table 7.5 in the next submission.	No	Implemented
IT-5E-2019-0001	No	5E Other Waste, PCDD/F, 2005, 2016, 2017	For 5E Other Waste the TERT noted that there is a lack of transparency regarding the origin of the emission factor used for the recalculation of building fires. The TERT notes that from the IIR it is clear that Italy as reaction on the Technical Correction from the 2019 review now implemented a more country specific methodology taking into account only fires that involved wood, cork and wooden load-bearing structures. The TERT notes that in doing so the more country specific methodology is not complete in the fires that are not taken into account now, mainly household furniture and upholstery (carpets, plastics, etc.) will be burned. Especially due to the presence of plastics this forms a potential source for PCCD/F emissions. This does potentially relate to under-estimate of emissions. This was raised during the 2019 NECD review. In response to a question raised during the review, Italy explained that the emission factor for PCCD/F originates from extrapolation of burning fuel wood and this is the reason for just taking building fires into account that involved wood, cork and wooden load-bearing structures. The TERT recommends that Italy makes their country specific approach complete by estimating the emissions from burning of household furniture and upholstery in the building fires that are currently missing.	TC 2019	Not implemented, more information has been provided in the IIR, chapter 7
IT-LPS-GEN-2020-0003		General, 2015	The TERT noted that in 2015, the same pair of longitude and latitude coordinates was assigned to more than one differently named LPS in 53 cases. The TERT recommends that Italy ensures that it provides unique longitude and latitude coordinates for each LPS in its future submissions.	No	It will be implemented for 2021 submission
IT-LPS-GEN-2020-0001		General, $PM_{2.5}$, HCB, 2015	For the LPS reporting, the TERT noted that emissions of several pollutants were not reported, including HCB and $PM_{2.5}$. In response to a question raised during the review Italy explained that LPS reporting is being prepared based on E-PRTR data which does not cover HCB and $PM_{2.5}$ but only total particles. The TERT noted that the issue is below the threshold of significance for a technical correction. The TERT recommends that Italy clarifies	No	It has been verified that no HCB and PM2.5 emissions occur from LPS plant

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
			whether any LPS have HCB and $PM_{2.5}$ emission above the reporting threshold and report any emissions above the reporting threshold in the next submission.		
IT-LPS-A-2020-0002		A Public Power, $PM_{2.5}$, 2015	The TERT recommends that Italy consider how to include $PM_{2.5}$ emissions for the LPS where PM_{10} emissions are reported for the next submission.	No	It will be implemented for 2021 submission
IT-LPS-A-2020-0001		A Public Power, SO_2, NO_X, NH_3, NMVOC, $PM_{2.5}$, BaP, PAHs, PCBs, HCB, Cd, Hg, Pb, PCDD/F, PM_{10}, CO, BC, 2015	The TERT recommends that Italy provide information to summarise the LPS dataset and how it was developed. Italy may wish to consider the recommended structure for an Informative Inventory Report contained in the 2014 Guidelines for Estimating and Reporting Emission Data	No	Implemented, more info in the IIR, chap. 10
IT-LPS-D-2020-0001		D Fugitive, 2015	For LPS-D and NFR 1B2aiv Oil: refining/storage there may be a case on noncompliant reporting. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Italy explained that emissions from refineries were reported in a different sector and that in the next submission they will report LPS data according to the different categories involved at plant level. Emission will be provided separately in the industry or fugitive sector according to their NFR codes and point source emission data which are available at NFR category level. The TERT recommends that Italy amends the reporting of fugitive and process emissions to be consistent with LPS requirements for the 2021 submission.	No	The recommendation will be taken in consideration in 2021 submission
IT-LPS-K-2020-0001		K Agriculture Livestock, NH_3, 2015	The TERT notes that for the year 2015, emissions are reported for 14 agricultural facilities in the E-PRTR database (v18) at a far higher level than they are reported in the LPS submission. In response to the review Italy indicated that this was an error in the LPS submission, and that the E-PRTR facility data is correct. The TERT recommends that Italy corrects this in the next LPS submission and provides any analytical comparison of E-PRTR facility data and national inventory estimates in its IIR description of LPS and Gridded estimates in future submissions.	No	It will be implemented for 2021 submission
IT-GRID-GEN-2020-0001		General, NH_3, NMVOC, NO_X, $PM_{2.5}$, 2015	The TERT recommends that Italy makes improvements to the gridding methods for the 2021 submission with distributions that reflect activities in all relevant GNFR sector for all pollutants and also provides a chapter in the IIR outlining the methods used to generate all of the gridded estimates, in accordance with the requirements outlined in the 2019 EMEP/EEA Guidebook. For example, regarding the F_RoadTransport sector Italy should follow methodology in section '3.4.3 Line sources to grids', the line sources such as road network should be intersected with the grid cells and allocate the emissions to the relevant grid cells proportionally.	No	More info in the IIR, chap 10

Observation	Key Category	NFR, Pollutant(s), Year(s)	Recommendation	RE or TC	Implementation
IT-GRID-B-2020-0001		B Industry, SO_2, NH_3, NMVOC, $PM_{2.5}$, PCBs, Cd, Hg, Pb, PCDD/F, PM_{10}, CO, 2015	For the GNFR category B_Industry the TERT noted that there is a lack of transparency regarding a misallocation of emissions between B_Industry and D_Fugitive GNFR sectors and an allocation of B_Industry emissions to the sector name 'B_IndustrialComb' which is not consistent with the guidelines. This does not relate to an over- or under-estimate of emissions. In response to a question raised during the review, Italy explained that in the next submission Italy will report gridded data according to the last available reporting guidelines and the relevant codes. The TERT recommends that Italy report gridded data according to the last available reporting guidelines and the relevant NFR codes in the next submission.	No	It will implemented for 2021 submission
IT-GRID-F-2020-0002		F Road Transport, NO_X, NMVOC, $PM_{2.5}$, PM_{10}, CO, 2015	The TERT recommends that Italy report road transport and rail emissions in the relevant separate GNFR sector categories in the next submission.	No	It will implemented for 2021 submission
IT-GRID-F-2020-0001		F Road Transport, SO_2, NH_3, Cd, Pb, PCDD/F, PAHs, 2015	The TERT recommends that Italy report road transport and rail emissions in the relevant separate GNFR sector categories in the next submission.	No	It will implemented for 2021 submission

A bilateral independent review between Italy and Spain was undertaken in the year 2012, with a focus on the revision of emission inventories and projections of both the Parties. With regard to the emission inventory the Italian team revised part of the energy sector of Spain, specifically the public power plants, petroleum refining plants, road transport and off-road categories, whereas the Spanish team revised the Industrial processes and solvent and other product use, and the LULUCF sectors of Italy. Results of these analyses are reported in a technical report. Aim of the review was to carry out a general quality assurance analysis of the inventories in terms of methodologies, EFs and references used, as well as analysing critical cross cutting issues such as the details of the national energy balances and comparison with international data (EUROSTAT and IEA) and use of plant specific information.

In addition, an official independent review of the entire Italian inventory was undertaken by the Aether consultants in 2013. Main findings and recommendations are reported in a final document, and regard mostly the transparency in the NIR, the improvement of QA/QC documentation and some pending issues in the LULUCF sector. These suggestions were considered in the implementation of the following inventories.

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 by the 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 2018, ISPRA has finalised the provincial inventory at local scale for the years 1990, 1995, 2000, 2005, 2010 and 2015 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 http://www.sinanet.isprambiente.it/it/sia-ispra/inventaria. Methodologies used for a previous reporting cycle are described in a related publication (ISPRA, 2009).

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 a 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.

A proper archiving and reporting of the documentation related to the inventory compilation process is also part of the national QA/QC programme.

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 are documented and archived. The archive is organised 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

An overall uncertainty analysis for the Italian inventory related to the pollutants described in this report has not been assessed yet. 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 Report* 2021 (ISPRA, 2021 [a]).

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, a planned improvement for next submissions is the completion of such analysis.

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 are no 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.

There are a few emission sources not assessed yet: HMs, BC, PAH, dioxin and PCB non exhaust emissions from 1.A.3.b vii, road abrasion, PAH, dioxin and PCB emissions from 1.A.3.b v gasoline evaporation, BC, dioxin and PCB emissions from 1.A.3.b vi, automobile tyre and brake wear, 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 and NH_3 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, 2019), need further assessment for the applicability to the national circumstances. PAH emissions are not detailed in the four indicator compounds for all the categories; we should still estimate them for categories 1.A.1, 1.A.2 stationary, 1.A.3.a, 1.A.3.d ii, 1.A.4.c iii, 2.C.1, and 2.C.3, because for some categories emission factors are not fully available by compound. PM and black carbon emissions from the categories reported in the NFR under 2.A.5, quarrying and mining of minerals other than coal, construction and demolition and storage, handling and transport of mineral products, are not estimated because no information on activity data 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 $0.1 mg/Nm^3$ 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 occurred in almost all countries of the UNECE.

Figure 2.1 and Table 2.1 show the emission trend from 1990 to 2019. Figure 2.1 also illustrates the share of SO_X emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

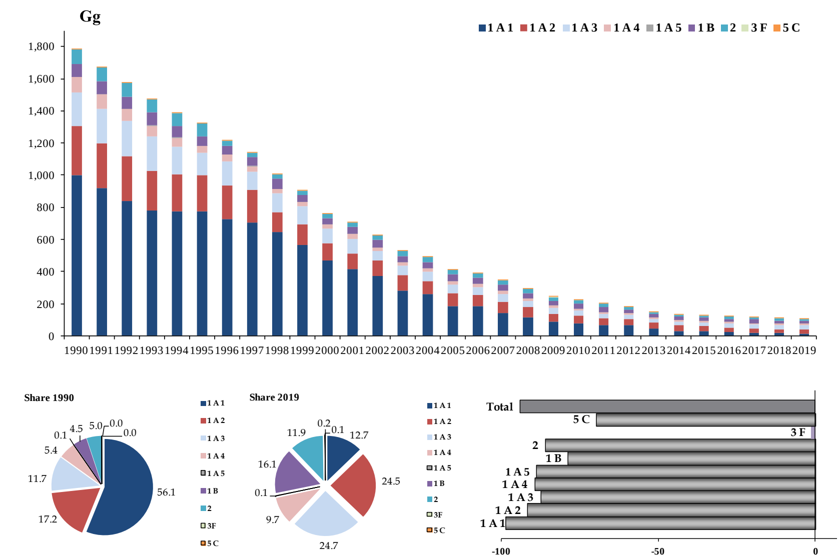


Figure 2.1 *SO_X emissions trend, percentage share by sector and variation 1990-2019*

Table 2.1 *SO_X emission trend from 1990 to 2019 (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Gg						
Combustion in energy and transformation industries	1,000.8	776.4	466.8	187.0	77.1	29.6	21.9	19.1	16.9	13.4
Non industrial combustion plants	82.3	32.5	25.0	22.7	12.1	10.3	10.3	10.1	10.4	10.2
Combustion - Industry	302.9	220.1	107.4	77.2	49.7	29.4	30.9	27.9	24.2	25.7
Production processes	157.2	126.1	51.1	60.5	46.2	30.5	29.4	32.6	29.3	25.8

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Gg						
Solvent and other product use	0.009	0.009	0.032	0.040	0.032	0.017	0.011	0.013	0.013	0.013
Road transport	129.3	71.3	11.9	2.2	0.4	0.3	0.4	0.4	0.4	0.4
Other mobile sources and machinery	98.3	84.1	83.9	50.6	29.1	22.0	21.9	22.0	23.3	25.8
Waste treatment and disposal	12.9	11.6	10.0	10.7	7.0	4.5	4.3	4.7	4.3	3.8
Agriculture	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	***1,783.6***	***1,322.1***	***756.4***	***411.0***	***221.6***	***126.7***	***119.2***	***116.9***	***108.9***	***105.0***

Figures show a general decline of SO_X emissions during the period, from 1,784 Gg in 1990 to 105 Gg in 2019. 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 revision of the time series. The new targets established for 2020 in the framework of the UNECE/CLRTAP Convention and for 2030 in the framework 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* (-92%), representing in 2019 about 13%, and 24% of the total, respectively. Emissions deriving from *non industrial combustion plants* and *road transport* show a strong decrease too (-88% and -100%, respectively), but these emissions represent only about 10% and 0.3% of the total in 2019. *Production processes* and *other mobile sources and machinery* also present a significant decreasing trend, showing an influence on the total of 25% and 25% and dropping by about -84% and -74%, respectively. SO_X emissions from agriculture and from solvent and other product use have been introduced but their contribute is irrelevant.

An explanation of the sectoral decreasing trend is outlined more in details 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 the 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 of 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 authorisation 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 both 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. Furthermore, there was a reduction in emissions in the production of cement regarding the type of fuel used in the process and the respective sulphur content.

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 1990-2019, from 2,125 Gg to 627 Gg. Figure 2.2 and Table 2.2 show emission figures from 1990 to 2019. Figure 2.2 also illustrates the share of NO_X emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

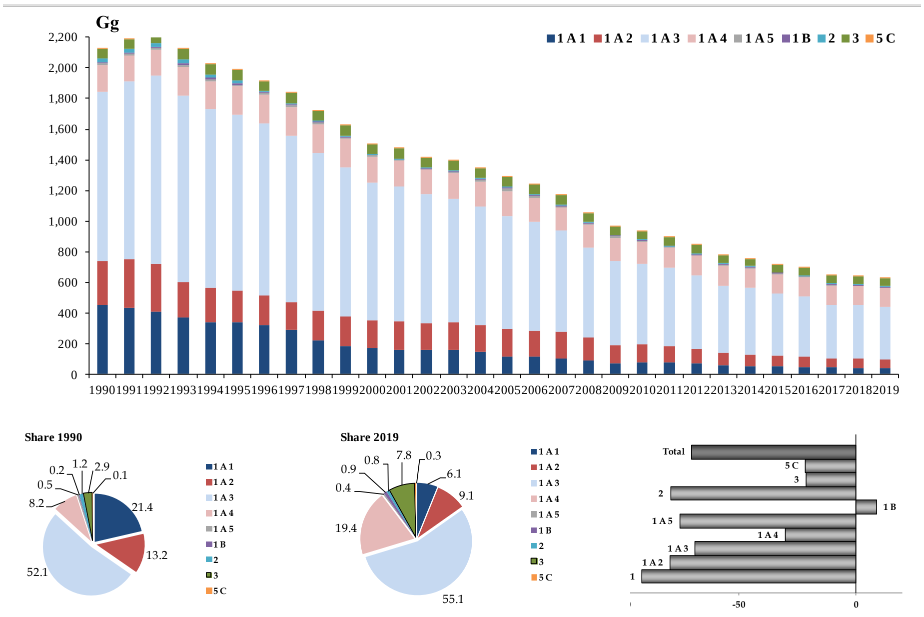


Figure 2.2 *NO_X emission trend, percentage share by sector and variation 1990-2019*

Table 2.2 *NO_X emission trend from 1990 to 2019 (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
Combustion in energy and transformation industries	457.4	344.3	172.6	117.9	81.3	52.4	48.1	45.6	41.6	38.7
Non industrial combustion plants	64.2	65.5	64.8	74.9	85.5	86.2	86.5	87.3	86.4	86.3
Combustion - Industry	250.5	182.2	153.9	155.3	99.1	60.8	61.1	54.2	53.1	52.7
Production processes	29.9	31.0	9.2	16.0	10.7	9.5	8.5	10.7	10.5	10.5
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	1039.7	777.2	628.8	421.9	327.4	313.3	269.4	266.6	252.7
Other mobile sources and machinery	261.5	258.5	260.1	233.0	183.1	129.9	127.3	124.6	129.1	134.6
Waste treatment and disposal	2.9	3.1	2.6	2.9	2.6	2.4	2.4	2.4	2.3	2.3
Agriculture	62.0	64.5	63.7	60.0	49.8	49.8	52.1	51.5	49.4	48.7
Total	***2,124.7***	***1,988.9***	***1,504.4***	***1,289.0***	***934.2***	***718.6***	***699.4***	***645.8***	***639.1***	***626.7***

Total emissions show a reduction of about 71% from 1990 to 2019, 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 already 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 2019), which shows a reduction of 75% between 1990 and 2019; *other mobile sources and machinery* in 2019 contributes to the total emissions for 21% and have reduced by 49% from 1990. *Combustion in energy* and in *industry* shows a decrease of about 92% and 79%, respectively, having a share on the total of about 6% and 8% in 2019, respectively. Among the sectors concerned, the only one which highlights an increase in emissions is *non industrial combustion plants* showing an increase by 34%, accounting for 14% 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, 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 authorisation 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 are equipped with heating system 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 (MSE, several years) and derived from regional or incomplete surveys. From 2013 this 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 NOx 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) on light vehicles.

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.

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 1990-2019, from 467 Gg to 355 Gg. Figure 2.3 and Table 2.3 report the emission figures from 1990 to 2019. Figure 2.3 also illustrates the share of NH_3 emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

According to the National Emission Ceilings Directive, the target value of emissions for 2010 amounts to 419 Gg which was achieved. The new 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.

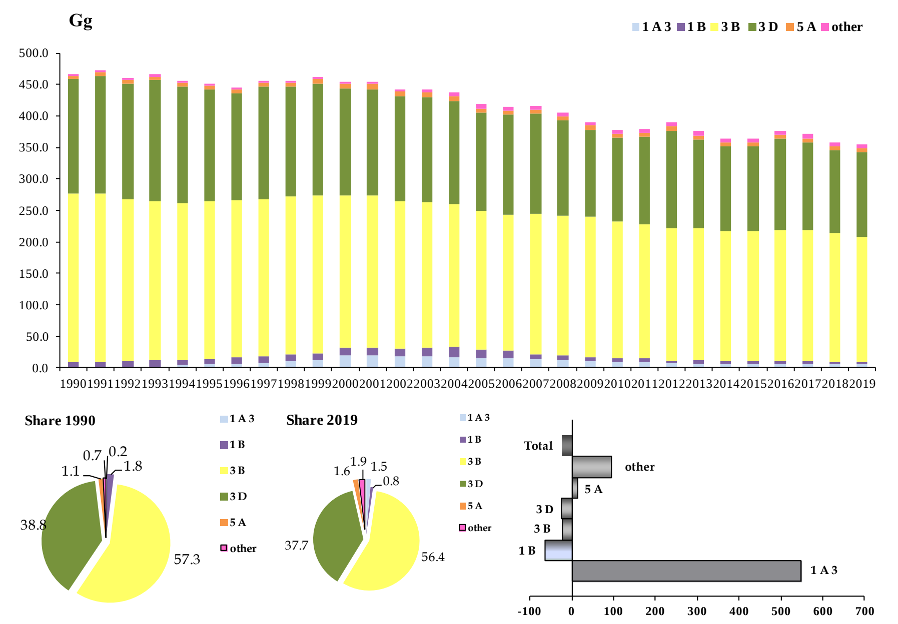


Figure 2.3 *NH_3 emission trend, percentage share by sector and variation 1990-2019*

Table 2.3 *NH_3 emission trend from 1990 to 2019 (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
Combustion in energy and transformation industries	0.3	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.1
Non industrial combustion plants	1.1	1.1	1.0	1.0	1.8	1.6	1.5	1.7	1.3	1.3
Combustion - Industry	0.5	0.6	0.6	4.0	1.6	1.0	1.2	1.2	1.1	1.0
Production processes	0.9	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.5
Solvent and other product use	0.38	0.38	0.42	0.39	0.38	0.33	0.32	0.32	0.31	0.30
Geothermal production	8.4	9.0	12.3	13.3	6.0	4.1	4.7	5.5	2.9	2.9
Road transport	0.8	5.1	19.9	14.9	9.3	5.7	5.4	5.1	5.3	5.2
Other mobile sources and machinery	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste treatment and disposal	5.2	6.5	7.4	7.6	7.1	8.6	8.5	8.5	8.6	8.7
Agriculture	449	428	412	377	350	342	354	348	338	335
Total	***466.7***	***451.6***	***453.9***	***419.0***	***377.1***	***364.3***	***376.6***	***370.8***	***358.4***	***354.7***

In 2019 *agriculture* is the main source of emissions, with a 94% contribution out of the total NH_3 emissions; from 1990 to 2019 emissions from this sector show a decrease of about 26%. Emissions from *road transport* show a strong increase, but the share on the total is 1.5%. Emissions from *waste treatment and disposal*, accounting also only for 2.5% of the total, show an increase of about 66% because of the increase of NH_3 emissions from anaerobic digestion at biogas facilities. Emissions from *non industrial combustion plants* show a relevant increase, but in 2019 the contribution to total emissions is 0.4%. Emissions from *combustion in energy and transformation industries* as emissions from *combustion in industry* are not relevant accounting for 0.04% and 0.3% respectively. Emissions from *production processes* show a reduction of about 37%, but also this contribution is irrelevant as well as emissions from *solvent and other product use*. Finally, emissions from *geothermal production* contribute in 2019 for 0.8% 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 1990-2019. Figure 2.4 and Table 2.4 illustrate the emissions values from 1990 to 2019. Figure 2.4 also illustrates the share of NMVOC emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

Figure 2.4 *NMVOC emission trend, percentage share by sector and variation 1990-2019*

The total emission trend shows a reduction of about 55% between 1990 and 2019, from 1,994 Gg to 894 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 new target established in the framework of the UNECE/CLRTAP Convention for 2020 is equal to 65% of 2005 emission level. 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 40% and showing a decrease of about 41%. The main reductions relate to the *road transport* sector (-87%), accounting for 11% of the total and to the sector of *extraction and distribution of fossil fuels/geothermal energy* (-62%), accounting only for 4%. Emissions from *agriculture* decrease of about 15%, accounting for 14% of the national total. Emissions from *other mobile sources and machinery*, accounting for 3% of the total, decrease of about 82%. Emissions from *non industrial combustion plants* show the largest increase (68%), accounting for 19%. Emissions from *waste treatment and disposal* and *combustion in industry* show a decrease of about 8% and 7%, respectively, but 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 2019 (Gg)*

	1990	1995	2000	2005	2010 *Gg*	2015	2016	2017	2018	2019
Combustion in energy and transformation industries	7.6	7.4	6.1	5.6	4.9	3.7	3.8	4.0	3.7	3.7
Non industrial combustion plants	102.8	112.9	113.3	121.8	216.3	188.7	185.8	200.5	173.9	173.0
Combustion - Industry	7.2	8.0	8.4	8.4	6.7	6.7	6.7	6.8	6.8	6.7
Production processes	113.8	103.3	88.5	92.3	74.5	57.1	55.2	55.4	53.7	54.6
Extraction and distribution of fossil fuels	90.9	103.7	56.6	53.9	49.2	38.1	40.2	39.3	36.2	34.2
Solvent and other product use	610.8	560.1	495.7	480.2	393.4	316.6	312.4	344.4	355.3	358.8
Road transport	767.1	878.7	609.2	359.3	184.7	126.7	117.3	112.5	107.2	102.1
Other mobile sources and machinery	133.4	122.0	97.6	73.7	51.0	30.0	27.2	25.9	25.4	24.6
Waste treatment and disposal	11.3	13.1	12.8	13.4	12.2	11.0	10.9	10.7	10.4	10.4
Agriculture	148.8	149.5	142.1	131.7	124.6	122.1	124.5	125.1	124.8	126.3
Total	***1,993.7***	***2,058.7***	***1,630.3***	***1,340.3***	***1,117.3***	***900.7***	***884.2***	***924.7***	***897.4***	***894.3***

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.

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 provide 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 finalised, 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 1990-2019, from 6,797 Gg to 2,062 Gg. The emission figures from 1990 to 2019 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 2019, as well as the total and sectoral variation from 1990 to 2019.

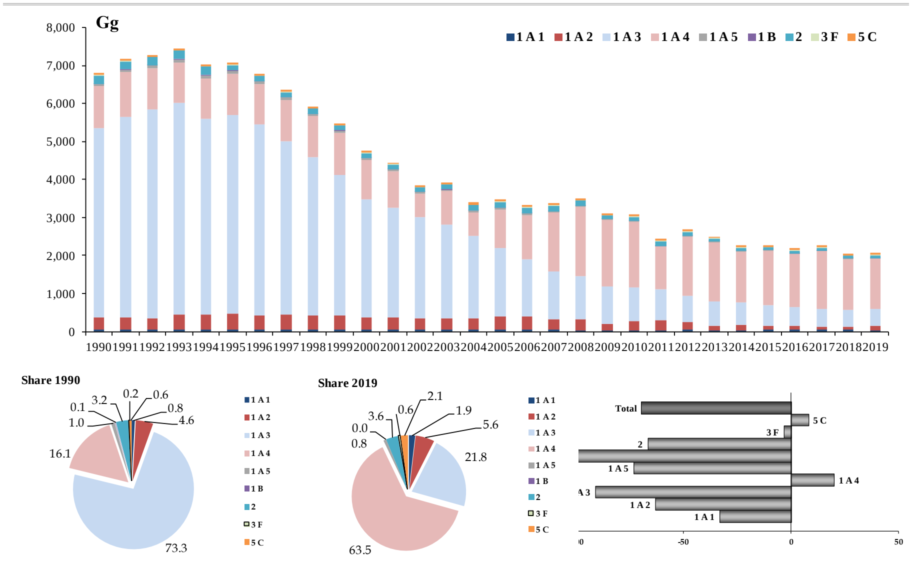


Figure 2.5 *CO emission trend, percentage share by sector and variation 1990-2019*

Table 2.5 *CO emission trend from 1990 to 2019 (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Gg						
Combustion in energy and transformation industries	58.9	54.1	54.4	53.9	34.5	39.9	44.0	44.5	39.6	38.6
Non industrial combustion plants	795.1	894.0	913.1	930.4	1,664.9	1,395.4	1,352.7	1,475.5	1,289.1	1,267.8
Combustion - Industry	305.6	410.9	314.6	326.0	233.6	92.8	100.8	81.9	80.8	110.0
Production processes	223.7	139.8	129.2	143.6	105.0	63.6	68.6	71.8	70.8	69.6
Solvent and other product use	5.1	5.1	5.7	5.3	5.1	4.4	4.3	4.3	4.2	4.0
Road transport	4,874.5	5,106.1	2,973.8	1,681.2	776.3	479.0	430.4	402.6	384.9	386.5
Other mobile sources and machinery	480.5	402.5	302.9	263.4	193.9	135.9	131.7	122.5	126.3	129.8
Waste treatment and disposal	40.7	46.9	45.4	50.5	47.2	47.0	48.9	46.0	44.3	44.0
Agriculture	12.5	12.2	12.1	13.1	12.5	12.7	13.6	12.4	12.2	12.0
Total	***6,796.5***	***7,071.6***	***4,751.1***	***3,467.4***	***3,072.9***	***2,270.7***	***2,195.1***	***2,261.3***	***2,052.2***	***2,062.2***

The decrease in emissions (-70%) 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 2019 of about 90%. Specifically, by sector, emissions from *road transport* and *other mobile sources and machinery*, accounting in 2019 respectively for 19% and 6% of the total, show a decrease from 1990 to 2019 of about 92% and 73% respectively. On the other hand, emissions from *non industrial combustion plants*, representing about 61% of the total in 2019, show a strong increase between 1990 and 2019, equal to 59% due to the increase of wood combustion for residential heating.

Figures show an increase in emissions from *waste treatment and disposal* too (8%), whose share is 2% of the total and a slight decrease (-3%) 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 1990-2019, from 293 Gg to 172 Gg. Figure 2.6 and Table 2.6 illustrate the emission trend from 1990 to 2019. Figure 2.6 also illustrates the share of PM10 emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

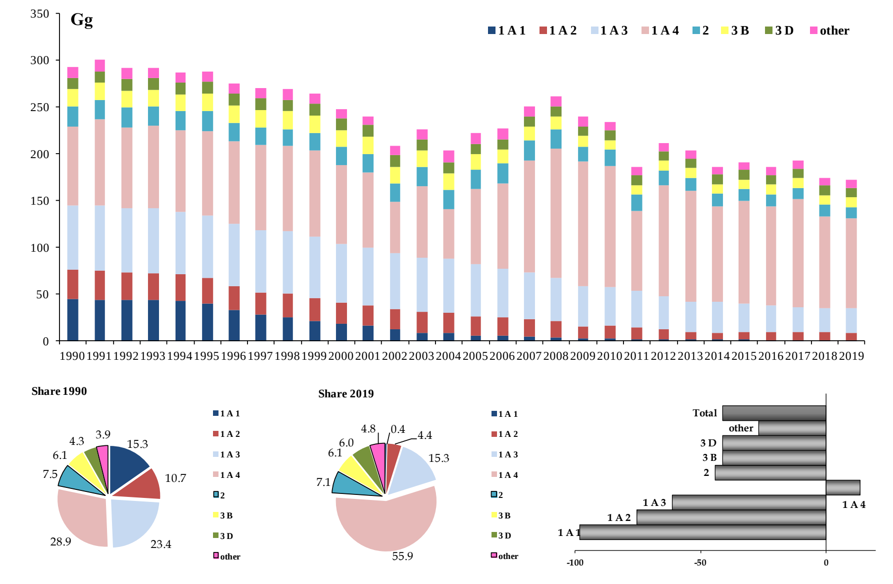


Figure 2.6 *PM10 emission trend, percentage share by sector and variation 1990-2019*

Table 2.6 *PM10 emission trend from 1990 to 2019 (Gg)*

	1990	1995	2000	2005 *Gg*	2010	2015	2016	2017	2018	2019
Combustion in energy and transformation industries	44.8	39.6	18.4	5.9	2.8	1.2	1.0	0.9	0.8	0.7
Non industrial combustion plants	67.8	71.2	68.6	68.6	123.1	106.8	103.4	113.0	95.1	94.0
Combustion - Industry	27.6	25.1	18.6	17.9	12.4	7.7	7.9	7.8	8.0	7.4
Production processes	23.5	23.0	20.2	21.6	17.2	12.3	12.2	12.3	12.4	12.5
Extraction and distribution of fossil fuels	0.7	0.6	0.6	0.8	0.7	0.6	0.5	0.5	0.4	0.3
Solvent and other product use	2.8	2.8	3.8	3.8	3.4	2.6	2.3	2.3	2.3	2.2
Road transport	58.7	57.6	52.6	46.3	33.3	24.4	22.8	20.9	20.4	20.0
Other mobile sources and machinery	31.6	32.1	30.5	25.1	15.9	10.0	9.6	9.0	9.0	9.2
Waste treatment and disposal	2.7	3.0	2.9	3.1	2.9	3.0	3.2	3.1	2.9	2.9

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Gg						
Agriculture	32.7	33.2	32.1	29.6	22.6	22.7	23.3	22.9	22.9	22.9
Total	***292.9***	***288.0***	***248.1***	***222.6***	***234.4***	***191.2***	***186.2***	***192.7***	***174.3***	***172.0***

From 1990 to 2019 the trend shows a reduction of about 41%. A considerable amount of emissions is mostly to be attributed to *non industrial combustion plant* (55% in 2018) which is increasing its emissions, about 39%, due to the increase of wood combustion for residential heating.

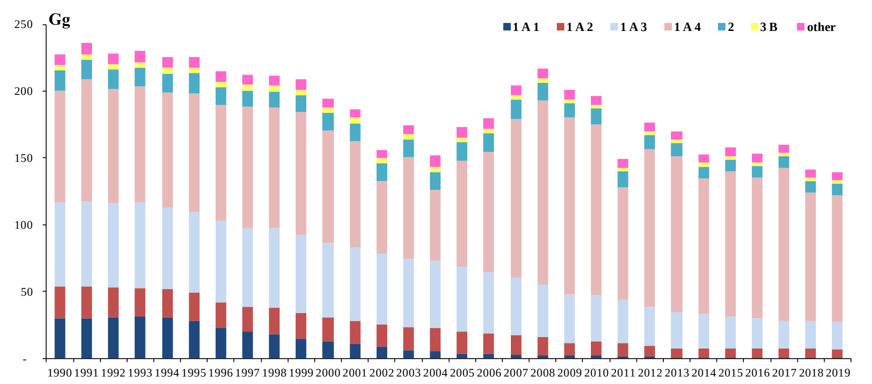
Agriculture sector, accounting for 13% of total emissions in 2019, reduced its emissions by 30% in 2019 respect to 1990, due to a reduction in emissions from livestock, which fall by about 40%, and a reduction in emissions from crops, which fall by about 19% due to a reduction in the area of arable land in 2019 compared to 1990.

Road transport accounts for 12% of total emissions in 2019 and decrease by 66% due to the introduction of the relevant European Directives controlling and limiting PM emissions at the car exhaust pipe.

In 2019 *other mobile sources and machinery,* accounting for 5% of the total, shows a reduction of about 71% 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 71%. Emissions from *production processes* accounting for 7% of the total in 2019 decrease of about 47% between 1990 and 2019. The largest decrease (-98%) is observed in emissions deriving from *combustion in energy and transformation industries,* whose contribution to total emissions is almost irrelevant in 2019 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 2019, with a variation from 227 Gg to 139 Gg. Figure 2.7 and Table 2.7 illustrate the emission trend from 1990 to 2019. Figure 2.7 also illustrates the share of PM2.5 emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.



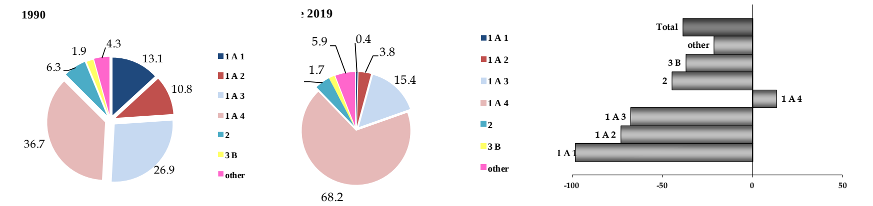


Figure 2.7 *PM2.5 emission trend, percentage share by sector and variation 1990-2019*

Table 2.7 *PM2.5 emission trend from 1990 to 2019 (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Gg						
Combustion in energy and transformation industries	30.1	27.8	12.7	3.7	1.8	0.8	0.7	0.6	0.6	0.5
Non industrial combustion plants	66.9	70.6	67.9	67.9	121.8	105.6	102.2	111.7	94.0	92.8
Combustion - Industry	19.9	18.3	14.0	13.6	9.8	6.3	6.4	6.4	6.6	6.2
Production processes	13.5	13.0	10.9	11.5	9.4	6.8	6.9	6.9	6.9	6.7
Extraction and distribution of fossil fuels	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Solvent and other product use	2.7	2.7	3.3	3.2	2.9	2.3	2.1	2.1	2.1	2.0
Road transport	53.3	51.5	46.0	39.3	26.8	18.1	16.8	15.3	14.6	14.1
Other mobile sources and machinery	31.5	32.0	30.4	25.0	15.9	9.9	9.6	9.0	9.0	9.1
Waste treatment and disposal	2.4	2.6	2.5	2.7	2.5	2.6	2.8	2.7	2.6	2.5
Agriculture	7.0	6.9	6.8	6.4	5.2	5.3	5.6	5.3	5.3	5.3
Total	***227.5***	***225.4***	***194.6***	***173.4***	***196.2***	***157.8***	***153.1***	***160.1***	***141.5***	***139.3***

In 2018, 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 2019 of about 39%. Specifically, emissions from *road transport*, accounting for 10% of total emissions, decrease of about 71%. Emissions from *other mobile sources and machinery* show a reduction of 72%, accounting in 2019 for 7% of total emissions. Emissions from *non industrial combustion plants* and from *combustion in industry* account for 67% and 4% of the total respectively, but while the former shows an increase of about 39%, the latter decreases by about 69%.

Agriculture sector, accounting for 4% of total emissions in 2019, reduced its emissions by 24% in 2019 respect to 1990. Emissions from *waste treatment and disposal*, accounting for 2% of the total in 2019, show an increase of about 6%. The largest decrease is observed for *combustion in energy* and *transformation industries* (-98%), being the influence on the total in 2019 lower than 1%.

For the explanation of the trends see what already 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 2019, with a variation from 47 Gg to 18 Gg. Figure 2.7 and Table 2.7 illustrate the emission trend from 1990 to 2019. Figure 2.7 also illustrates the share of BC emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

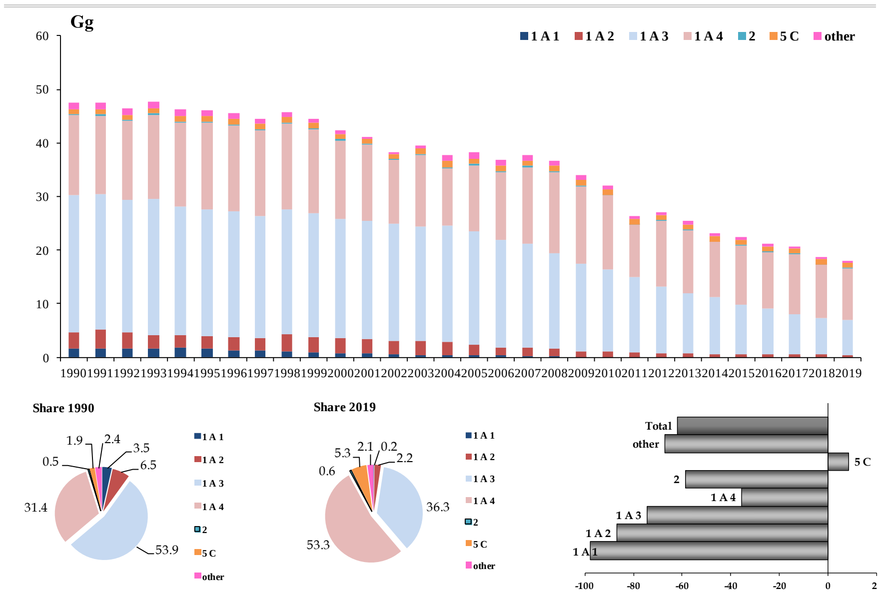


Figure 2.8 *BC emission trend, percentage share by sector and variation 1990-2019*

Table 2.8 *BC emission trend from 1990 to 2019 (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
Combustion in energy and transformation industries	1.7	1.6	0.8	0.3	0.1	0.0	0.0	0.0	0.1	0.0
Non industrial combustion plants	5.4	5.7	5.6	5.7	10.3	9.1	8.8	9.6	8.4	8.4
Combustion - Industry	0.7	0.6	0.5	0.5	0.4	0.3	0.3	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	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0
Road transport	24.0	22.3	20.8	19.6	14.0	8.3	7.5	6.6	5.8	5.4
Other mobile sources and machinery	14.1	14.5	13.4	10.6	5.8	3.4	3.2	2.9	2.8	2.7
Waste treatment and disposal	0.9	1.0	0.9	1.0	1.0	1.0	1.1	1.0	1.0	1.0
Agriculture	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	***47.5***	***46.2***	***42.4***	***38.3***	***32.0***	***22.4***	***21.2***	***20.7***	***18.7***	***18.0***

Total emissions show a global reduction from 1990 to 2019 of about 62%. Specifically, emissions from *road transport*, accounting for 30% of total emissions, decrease of about 77%. Emissions from *other mobile sources and machinery* show a reduction of 81%, accounting in 2019 for 15% of total emissions. Emissions from *non industrial combustion plants* and from *combustion in industry* account for 46% and 1% of the total respectively, but while the former shows an increase of about 55%, the latter decreases by about 63%. I*ndustrial processes*, accounting for less than 1% in 2019, decrease of 74%. Emissions from *waste treatment and disposal*, accounting for 5% of the total in 2019, show an increase of about 8%. The largest decrease is observed for *combustion in energy* and *transformation industries* (-98%), being the influence on the total in 2019 less than 1%.

For the explanation of the trends refer to previous paragraph.

2.3 HEAVY METALS (PB, CD, HG)

This section provides an illustration of the most significant developments between 1990 and 2019 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 2019, varying from 4,280 Mg to 199 Mg. Figure 2.9 and Table 2.9 illustrate the emission trend from 1990 to 2019. Figure 2.9 also illustrates the share of Pb emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

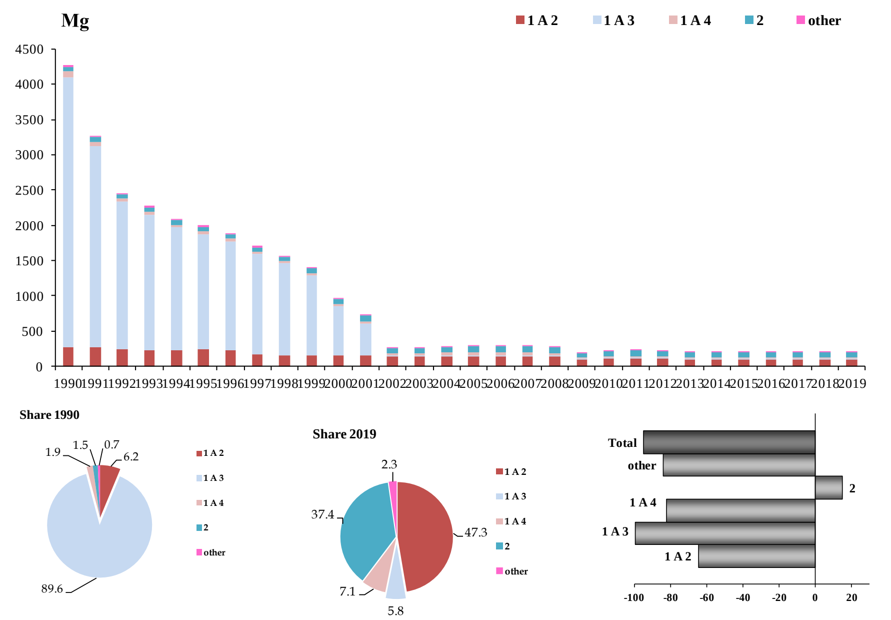


Figure 2.9 *Pb emission trend, percentage share by sector and variation 1990-2019*

Table 2.9 *Pb emission trend from 1990 to 2019 (Mg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Mg						
Combustion in energy and transformation industries	4.0	4.0	3.6	3.8	3.1	2.7	2.4	2.3	2.0	1.7
Non-industrial combustion plants	14.5	16.6	22.4	46.3	16.5	15.1	14.6	15.2	14.4	14.2
Combustion - industry	263.1	234.9	153.6	141.9	104.7	95.2	100.4	98.5	95.8	94.2
Production processes	63.7	68.2	67.3	74.2	69.5	66.1	68.7	73.4	75.6	71.5
Solvent and other product use	2.4	2.4	8.4	10.3	8.4	4.3	2.8	3.4	3.4	3.4
Road transport	3,782.3	1,617.3	690.0	13.2	12.3	12.2	11.0	10.1	10.5	10.5

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Mg					
Other mobile sources and machinery	142.2	44.2	13.3	1.1	1.1	1.1	1.1	1.1	1.2	1.3
Waste treatment and disposal	7.7	8.1	5.2	6.8	2.8	2.6	2.3	2.4	2.3	2.3
Agriculture	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	***4,280.0***	***1,995.7***	***963.8***	***297.6***	***218.3***	***199.3***	***203.2***	***206.5***	***205.2***	***199.0***

In 2019 emissions from *combustion in industry* have the most significant impact on the total (47%) and show a reduction of about 64%; this reduction is to be attributed primarily to *processes with contact,* which contribute with 59% to the sectoral reduction and 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, increased by about 12%, and represent 36% of the total. Emissions from *non industrial combustion plants* show a 2% decrease and represent, in 2019, 7% of the total. As to emissions from *transport* activities, because of changes 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 2019. Figure 2.10 also illustrates the share of Cd emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

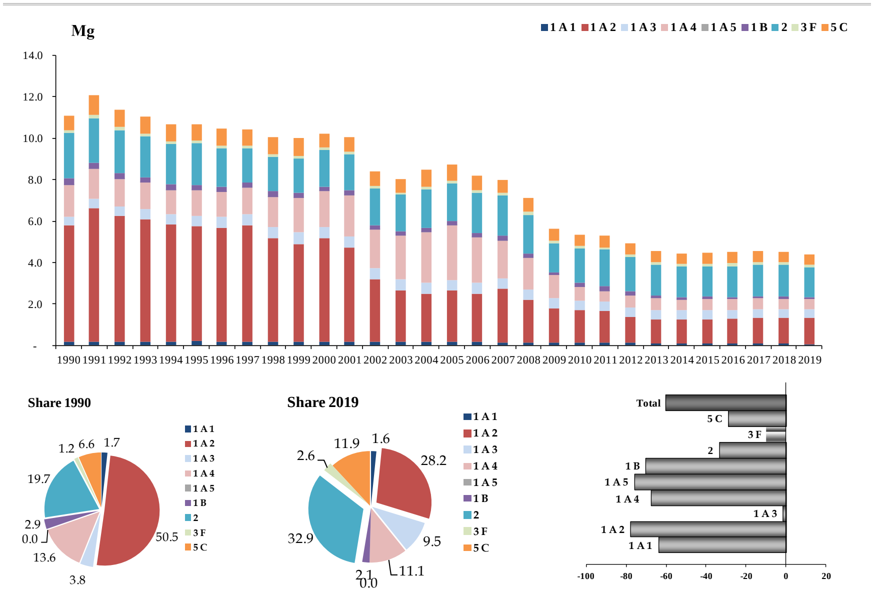


Figure 2.10 *Cd emission trend, percentage share by sector and variation 1990-2019*

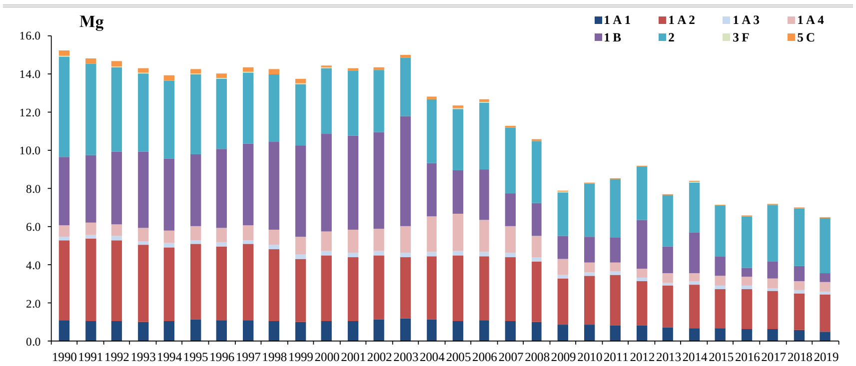
Table 2.10 *Cd emission trend from 1990 to 2019 (Mg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					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	1.2	1.2	1.2	1.2	1.2
Production processes	2.0	1.8	1.4	1.5	1.4	1.1	1.2	1.2	1.3	1.2
Solvent and other product use	0.5	0.5	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Road transport	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Other mobile sources and machinery	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Waste treatment and disposal	0.7	0.8	0.7	0.8	0.6	0.6	0.6	0.5	0.5	0.5
Agriculture	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	***11.1***	***10.7***	***10.2***	***8.7***	***5.3***	***4.5***	***4.5***	***4.6***	***4.5***	***4.4***

Emissions show a global reduction of 60% between 1990 and 2019, from 11.1 Mg to 4.4 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 78% and 68% respectively. Emissions from *production processes* decrease by about 41% and represent 27% of the total. Emissions from *waste treatment and disposal* (i.e. waste incineration), accounting for 12% of the total, register a reduction of about 29% while emissions from *road transport*, accounting for 9% of the total levels, decreased by 1% and emissions from *stubble burning in agriculture* account for 3% of the total and decrease of about 10%.

2.3.3 **Mercury (Hg)**

The national atmospheric emissions of mercury show a quite stable trend in the period 1990-2019. Figure 2.11 and Table 2.11 illustrate the emission trend from 1990 to 2019. Figure 2.11 also illustrates the share of Hg emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.



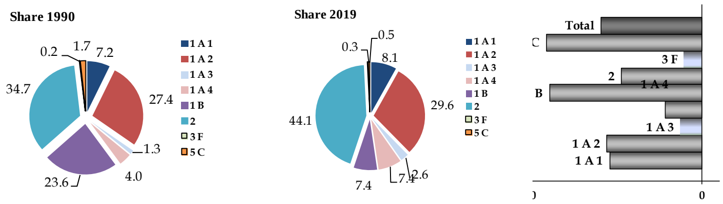


Figure 2.11 *Hg emission trend, percentage share by sector and variation 1990-2019*

Table 2.11 *Hg emission trend from 1990 to 2019 (Mg)*

	1990	1995	2000	2005	2010 *Mg*	2015	2016	2017	2018	2019
Combustion in energy and transformation industries	1.10	1.14	1.06	1.07	0.86	0.69	0.65	0.64	0.58	0.52
Non-industrial combustion plants	0.61	0.71	1.04	1.97	0.52	0.49	0.48	0.49	0.49	0.48
Combustion - industry	4.17	3.95	3.43	3.41	2.55	2.06	2.07	1.98	1.93	1.92
Production processes	5.47	4.36	3.59	3.36	2.87	2.70	2.74	3.01	3.07	2.92
Geothermal production	3.40	3.62	4.96	2.15	1.25	0.98	0.40	0.85	0.72	0.43
Road transport	0.19	0.22	0.23	0.23	0.19	0.17	0.17	0.16	0.17	0.17
Waste treatment and disposal	0.26	0.23	0.12	0.15	0.01	0.03	0.01	0.02	0.02	0.03
Agriculture	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	***15.22***	***14.26***	***14.46***	***12.36***	***8.28***	***7.15***	***6.56***	***7.18***	***7.00***	***6.49***

Emission trend shows a global reduction of about 57% from 1990 to 2019, varying from 15.2 Mg to 6.5 Mg. The general trend is driven by reduction of emissions in lead and zinc 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 - processes with contact*, accounting for 30% and decreasing by 54%; emissions from *production process - processes in iron and steel industries and collieries*, representing 45% of the total and increasing by 47%; emissions from *non industrial combustion plants* which represent 7% of the total and decrease by 21%. Emissions deriving from *combustion in energy and transformation industries*, accounting for 8%, show a 52% reduction. Emissions from *production process - processes in inorganic chemical industries*, not contributing to the total in 2019, show a reduction equal to 100% totally due to the technological changes for the production of chlorine. Emissions from *road transport* account for 3% and decrease of 12%. Emissions from *waste treatment and disposal* and *agriculture*, contributing to the total only for less than 1%, show a large reduction, equal respectively to 88% and 10%. Emissions from *geothermal production* account for 7% of the national total and shows a reduction of 87% with respect to 1990 due to the introduction of control and abatement system at the production plants.

2.4 PERSISTENT ORGANIC POLLUTANTS (POPS)

In this section, the most significant peculiarities of polycyclic aromatic hydrocarbons and dioxins, occurred between 1990 and 2019, will be presented.

2.4.1 Polycyclic aromatic hydrocarbons (PAH)

The national atmospheric emissions of polycyclic aromatic hydrocarbons decreased from 90 Mg to 65 Mg between 1990 and 2019. Figure 2.12 and Table 2.12 illustrate the emission trend from 1990 to 2019. Figure 2.12 also illustrates the share of PAH emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

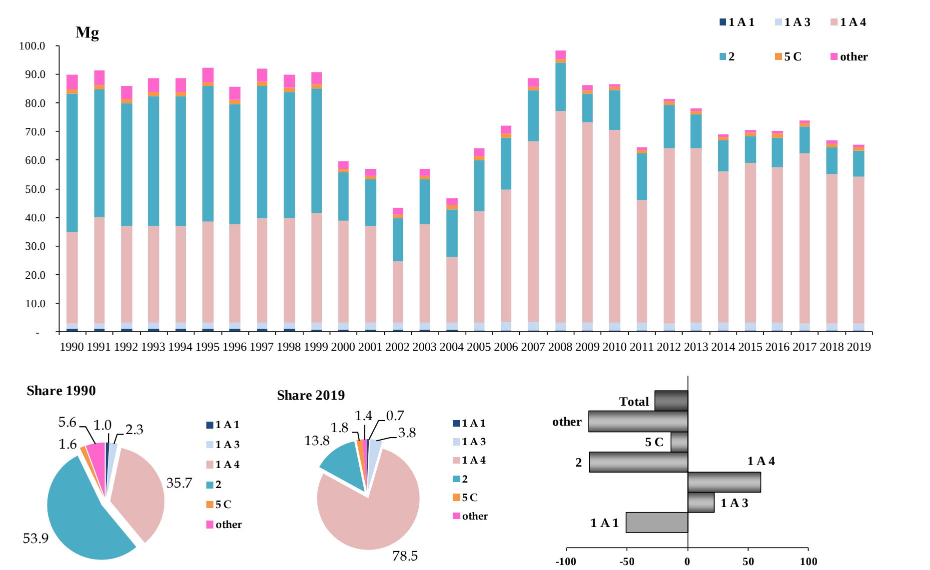


Figure 2.12 *PAH emission trend, percentage share by sector and variation 1990-2019*

Table 2.12 *PAH emission trend from 1990 to 2019 (Mg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Mg						
Combustion in energy and transformation industries	0.9	1.0	0.7	0.5	0.4	0.5	0.5	0.5	0.5	0.5
Non-industrial combustion plants	31.9	35.2	35.7	38.9	67.3	55.9	54.2	59.2	52.2	51.2
Combustion - industry	4.5	4.6	2.2	2.4	0.4	0.5	0.6	0.5	0.5	0.5
Production processes	48.4	47.4	16.8	17.7	14.1	9.3	10.5	9.6	9.4	9.0
Solvent and other product use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Road transport	2.0	2.0	2.2	2.6	2.6	2.6	2.6	2.4	2.5	2.4
Other mobile sources and machinery	0.3	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.3	0.3

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
				Mg						
Waste treatment and disposal	1.4	1.5	1.4	1.4	1.2	1.3	1.3	1.2	1.2	1.2
Agriculture	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total	***89.9***	***92.4***	***59.7***	***64.2***	***86.7***	***70.7***	***70.3***	***74.1***	***66.8***	***65.5***

Between 1990 and 2019, total emissions show a decrease of about 27%. Among the most significant changes, *non industrial combustion plants*, prevalently *residential plants*, account for 78% of the total in 2019 and show a strong increase (about 61%) due to the increase in wood consumption for heating.

Emissions from *production processes*, mainly *processes in iron* and *steel industries*, account for 14% of the total and show a decrease of 81% 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 a decrease of 14%. Emissions from *road transport*, accounting for 4% in 2019, show an increase of about 24%. The share of other subsectors is about 1%.

2.4.2 Dioxins

The national atmospheric emissions of dioxins show a decreasing trend between 1990 and 2019, with values varying from 503 g I Teq to 271 g I Teq. Figure 2.13 and Table 2.13 illustrate the emission trend from 1990 to 2019. Figure 2.13 also illustrates the share of dioxin emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

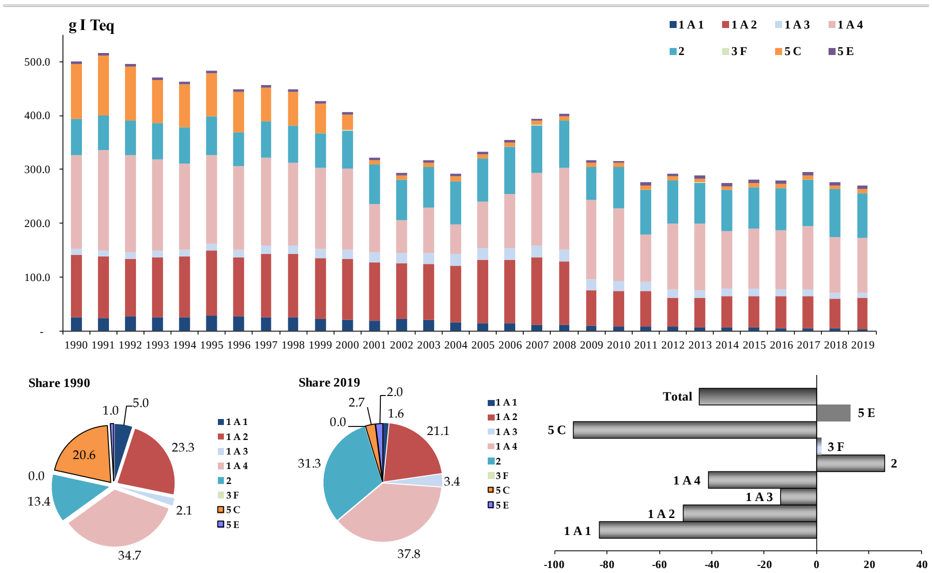


Figure 2.13 *Dioxin emission trend, percentage share by sector and variation 1990-2019*

Table 2.13 *Dioxin emission trend from 1990 to 2019 (g I Teq)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					g I Teq					
Combustion in energy and transformation industries	24.93	27.89	20.94	13.97	8.16	6.20	5.75	5.27	4.70	4.22
Non-industrial combustion plants	173.76	164.61	150.96	87.03	134.57	112.42	108.88	118.43	103.76	101.75
Combustion - industry	116.66	120.91	112.00	118.65	65.28	58.24	59.07	59.78	55.87	56.98
Production processes	67.20	71.68	70.66	78.59	76.16	76.79	78.78	86.05	88.92	84.46
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	10.66	13.60	18.17	21.38	20.18	13.61	12.66	11.48	10.00	9.18
Other mobile sources and machinery	1.29	1.44	1.33	1.55	1.19	0.94	1.04	1.01	1.07	1.10
Waste treatment and disposal	108.01	84.48	33.61	13.10	11.89	12.93	13.66	14.32	12.79	12.75
Agriculture	0.12	0.12	0.12	0.13	0.12	0.12	0.13	0.12	0.12	0.12
Total	***502.64***	***484.73***	***407.80***	***334.41***	***317.55***	***281.26***	***279.98***	***296.46***	***277.24***	***270.57***

The general trend shows a decrease from 1990 to 2019 equal to 46%, 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 2019, are observed in *waste treatment and disposal, combustion in energy and transformation industries* and *combustion in industry*, (-88%, -83% 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.

In 2019, the subsectors which have contributed most to total emissions are *non-industrial combustion plants, production processes and combustion in industry* accounting for 37%, 31% and 21% of the total respectively. In particular emissions from *production processes* show an increase of 26% in the period 1990-2019 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 1990-2019, varying from 139 kg to 10 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 2019. Figure 2.14 also illustrates the share of HCB emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

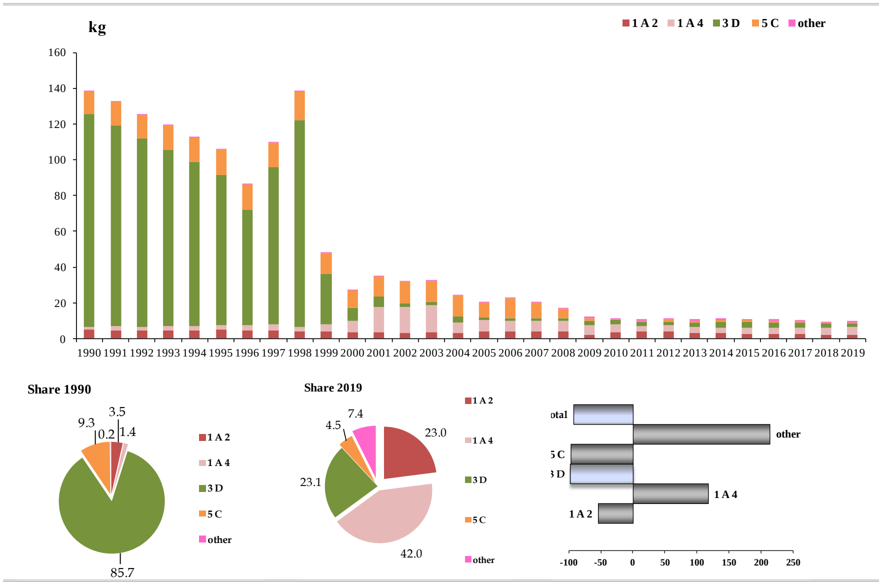


Figure 2.14 *HCB emission trend, percentage share by sector and variation 1990-2019*

Table 2.14 *HCB emission trend from 1990 to 2019 (Mg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Mg					
Combustion in energy and transformation industries	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Non-industrial combustion plants	0.002	0.003	0.006	0.006	0.004	0.003	0.003	0.004	0.004	0.004
Combustion - industry	0.005	0.005	0.004	0.004	0.003	0.003	0.003	0.002	0.002	0.002
Road transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
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	0.000	0.000
Agriculture	0.119	0.084	0.007	0.002	0.002	0.003	0.003	0.003	0.002	0.002
Total	***0.139***	***0.107***	***0.028***	***0.022***	***0.012***	***0.012***	***0.011***	***0.011***	***0.010***	***0.010***

The use of pesticide in *agriculture* category is the main driver for the decreasing trend of the HCB national emissions, emissions from this category show 98% decrease between 1990 and 2019. The second sector contributing to the general trend is *waste treatment and disposal*, in particular waste incineration - sludge incineration. Specifically, the considerable increase of 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 21% and 39% respectively. Emissions from *combustion in energy and transformation industry* and emissions from *non industrial combustion plants* show an increase of 222% and 118% respectively between 1990 and 2019. In the same years for emissions from *waste treatment and disposal* a decrease of 98% must be noted while emissions from combustion in industry show a decrease of 54%.

2.4.4 **Polychlorinated biphenyl (PCB)**

The national atmospheric emissions of polychlorinated biphenyl show a decreasing trend in the period 1990-2019, about -26%, from 152 kg to 112 kg. Figure 2.15 and Table 2.15 illustrate the emission trend from 1990 to 2019. Figure 2.15 also illustrates the share of PCB emissions by category in 1990 and 2019 as well as the total and sectoral variation from 1990 to 2019.

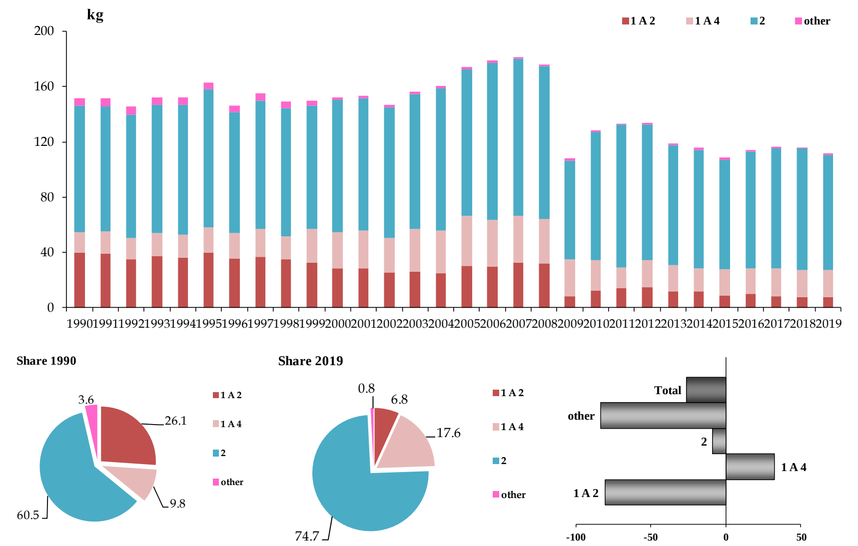


Figure 2.15 *PCB emission trend, percentage share by sector and variation 1990-2019*

Table 2.15 *PCB emission trend from 1990 to 2019 (Mg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Mg					
Combustion in energy and transformation industries	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Non-industrial combustion plants	0.015	0.018	0.025	0.036	0.022	0.019	0.018	0.020	0.019	0.019
Combustion - industry	0.040	0.040	0.029	0.030	0.013	0.009	0.010	0.008	0.008	0.008
Production processes	0.092	0.100	0.096	0.106	0.093	0.079	0.084	0.087	0.088	0.083
Road transport	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other mobile sources and machinery	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Waste treatment and disposal	0.005	0.005	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000
Total	**0.152**	**0.163**	**0.152**	**0.174**	**0.128**	**0.109**	**0.114**	**0.117**	**0.116**	**0.112**

Among the most significant variations, emissions from *combustion in industry* and from *production processes* represent 7% and 75% of the total respectively, showing the former a decrease of -81% and the latter of 9%. 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 (33%) between 1990 and 2019. The share of other sectors is about 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 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 Economic Development (MSE, several years (a)) and reported to the international energy organization, and from emission factors appropriate to the type of combustion and the pollutant.

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 2019, almost 99% of the total amount of waste incinerated is treated in plants with 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 in energy content applying the relevant factor as resulting from data provided by TERNA, which in 2019 is equal to 11.3 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 digester 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 as portable generators, compressors and cement mixers. Estimates are calculated taking in 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, 2016). COPERT II has been used for years 1994 and 1995 to estimate emissions and average emission factors for vehicles and diesel fuel consumption. Population data have 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 consumptions 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 in 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 factor reported in the European Directive 2004/26/EC Directive have been applied and introduced in the emission estimates.

In 2019 the energy sector accounts for more than 50% of total emissions for all the estimated pollutants, except for NMVOC, which accounts for 38%, PCB for 24% and ammonia for 2%. In particular, emissions from the energy sector are 94% of CO and BC, 92% of NO_X, 91% of PM2.5, 88% of SO_X and 83% of PAH national total emissions.

In 2019, the following categories are key categories for different pollutants: *public electricity and heat production* (1A1a), *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), *fugitive emissions from natural gas* (1B2b) and *other fugitive emissions from energy production* (1B2d).

The same categories are key categories for 1990, except (1B2b), and for the trend analysis. In addition, for 1990, petroleum refining (1A1b) for SO_X, PM10, *stationary combustion in chemical industries* (1A2c) for SO_X and PM10, *mobile combustion in manufacturing industries and construction* (1A2g vii) for BC, *stationary combustion in other industries* (1A2g viii) for SO_X, and *fugitive emissions from distribution of oil products* (1B2a v) for NMVOC emissions are also key categories.

3.2 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), the IPCC Guidelines (IPCC, 1997; IPCC, 2006) and the Good Practice Guidance (IPCC, 2000).

Specifically for road transport, the most recent version of COPERT 5 programme, version 5.2.2, has been used to calculate emissions (EMISIA SA, 2019); the updated version of the model has been applied for the whole time series. In paragraph 3.8 more detailed information is supplied on these figures.

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, 2020[a]). At national level, trends of the CLRTAP pollutants are described in the environmental data yearbook published by ISPRA (ISPRA, 2019).

The National Energy Balance, published by the Ministry of Economic Development, 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. On the other hand, basic activity data 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. Other data are communicated by different category associations.

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 http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni/fattori-di-emissione-per-le-sorgenti-di-combustione-stazionarie-in-italia/view as well as emission factors for road transport (1A3b) are available at http://www.sinanet.isprambiente.it/it/sia-ispra/fetransp/ .

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 2016 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). 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 regard only 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 submission we plan 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 fuelled main plants some HMs under the PRTR area available. For refineries a quite complete reporting is available for selenium and zinc. In the first case the average EFs is 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.

Moreover for 1A1c category and in particular for coke production according to the review (EEA, 2019) PAH emission factor 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 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 colleagues from the Ministry of Environment (IMELS) 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 to 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 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 we believe that official data, as air emission values, communicated by the operators in the EU official frameworks, 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 in particular 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.

For 1A2 categories, estimates for chemical, food processing, and other sectors (as textile, mechanics, extraction) are based on fuel consumption where EMEP/CORINAIR 2007 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 2016 Guidebook at fuel level. Emissions of NH3 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 with 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 2016 Guidebook are not appropriate because of 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.

More in detail 1A2a includes combustion activities from the iron and steel sector as blast furnace cowpers, sinter plants and reheating furnaces. In 1990 there were four integrated iron and steel plants in Italy. In 2019, there are only two of the above mentioned plants, one of which lacks BOF; oxygen steel production represents about 18.2% of the total production and the arc furnace steel the remaining 81.8% (FEDERACCIAI, several years). Currently, long products represent about 46% of steel production in Italy, flat products about 42%, and pipe the remaining 12%. Most of the flat production derives from only one integrated iron and steel plant 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 factor with last available data is planned for the next submission. Cd emissions refer to blast furnaces, sinter and reheating activities and are driven by sinter plant productions, which account for more than 65% of the total; emission factors are those reported by the main Italian plant and emissions have been revised since 2003 to 2019 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.

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, 2021). 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 notation key NA is reported. HCB and PCB emissions from secondary aluminum production are planned to be estimated and reported for the next submission based on the information available in a national study. Dioxin emissions from this category is driven by emissions from secondary aluminium 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 EF 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 one order of magnitude lower than those from aluminum production (10% of the total of 1A2b). An investigation is ongoing with the aim to report 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 SOX, NOX, 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, up to 2013, production SOX, 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. For secondary aluminium production PAH and dioxins country specific emission factors have been used (ENEA-AIB-MATTM, 2002). Thanks to the investigation above mentioned EFs for NOx, SOx, PM10, Pb, Cd e Zn from zinc and lead production have been updated on the basis of data at plant level.

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 EF handbook) while for lime production PM emission factors referring to the complete process are used (from USEPA 1996 EF 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.

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 these data are 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, they are considered as verification. EPER/EPRTR data are yearly available from 2002 while ETS data from 2005 and LCP data from 1990 all on 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 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 we ask 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 we estimate emissions at plant level and compare them with those submitted in the EPRTR and LCP. Also in this case we ask for clarifications to the reporting plant if necessary.

3.3 TIME SERIES AND KEY CATEGORIES

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 under the UNECE convention; specifically, for the main pollutants, in 2019 the sector accounts for:

- 94% in national total CO emissions;
- 94% in national total BC emissions;
- 91% in national total NO_X emissions;
- 88% in national total PM2.5 emissions;
- 88% in national total SO_X emissions;
- 84% in national total PAH emissions.

Moreover, the sector is also an important source for heavy metals; specifically in 2019, energy sector is responsible for 53% of total Cd emissions, 55% for Hg and 61% for lead emissions.

There are no differences as compared to the sectoral share in 1990, except for lead whose contribution in 1990 was 98% of total emissions, 30% higher than in 2019 and for PAH whose contribution in 1990 was 44%, 40% lower than in 2019.

One of the most important source of emissions in the sector and key category, in 2019, is represented by *road transport* (1A3b), at least for the main pollutants: NO_X (40.3%), BC (30.1%), CO (18.7%), NMVOC (11.4%), Cd (9.1%) and particulate matter (PM10 11.6%, PM2.5 10.1%). There has been a strong reduction in lead emissions from 1990 to 2019 in *road transport* due to replacement of lead gasoline. An in depth analysis of the road transport category and its emission trends is reported in paragraph 3.8.

Manufacturing industries and *construction* (1A2) is a main source of heavy metals and POPs, accounting for about 47% of lead total emissions, 28% for cadmium, 30% for mercury, 21% for HCB, and 21% for dioxin. The sector is key category also for PM10 and PM2.5 (4%) as well as SO_X, NOx and CO, about 24%, 8% and 5% of total emissions. The main sectors are iron and steel sector, which is key for SO_X, CO, Pb, Cd, Hg and HCB, the non-ferrous metal sector, key for Hg 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 source of SO_X emissions in 2019 with a share of 6.4%, HCB (6.8%), Hg (6.6) and NO_X emissions (4.3%). 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 authorisation 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 authorisations, for the authorisation 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 2019 in Italy there are still 8 coal plants, of which only 7 fully working, and 2 fuel oil plant out of around 150 power plants included in this source category. With exception of few biomass plants and some gasoil stationary engines in the small islands, the other plants are natural gas combined cycle thermoelectric power plant.

Petroleum refining (1A1b) is not a key category in 2019. 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.

National *navigation* (1A3d ii) is key category for SO_X (23.8%), NO_X (13.2%), PM10 (3.6%), PM2.5 (4.5%) and BC (5.9%) .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 2019 for 19.4% and 20.2% of national total, respectively; SO_X emission account for 9.7%; CO emissions account for 63.5%; Cd emissions account for 11.1%; PM10 and PM2.5 emissions account for 55.9% and 68.2% respectively while BC emissions account for 53.3%; dioxin is 37.6%, PAH is 78.5% , PCB is 17.4% and HCB is 39.2% of national totals. These emissions are prevalently due to biomass combustion, in winter, and they are also becoming critical for air quality issues and for HCB due to the increase of combustion of waste with energy recovery reported under the sector. An in depth analysis of this category is reported in the paragraph 3.12.

Fugitive emissions in refinery from fossil fuel distribution and storage (1B2a iv) is key category in 2019 for SO_X emissions (12.7%). Total SO_X fugitive emissions from distribution of fossil fuels account for 14.0% of the total. *Fugitive emission from natural gas* (1B2b) is key category for NMVOC emissions accounting for 2.1% of national total emissions and *Fugitive emissions from geothermal energy production* is key category for Hg for 6.6% of national total emissions.

Table 3.1 *Key categories in the energy sector in 2019*

	1A1 a	1A1 b	1A1 c	1A2	1A2 g vii	1A3 a i	1A3 a ii	1A3 b i	1A3 b ii	1A3 b iii	1A3 b iv	1A3 b v	1A3 b vi	1A3 b vii	1A3 c	1A3 d ii	1A3 e i	1A4 a i	1A4 bi	1A4 bii	1A4 c	1A5 b	1B1 a	1B1 b	1B2
SO_X	6.4	4.6	1.7	24.4	0.0	0.4	0.2	0.2	0.0	0.1	0.0				0.0	23.8	0.0	4.3	5.4	0.0	0.1	0.1			16.1
NO_X	4.3	1.4	0.4	8.4	0.7	0.9	0.4	20.3	6.6	13.0	0.5				0.3	13.2	0.1	5.5	6.3	0.0	7.6	0.4			0.9
NH_3	0.0	0.0	0.0	0.3	0.0			1.3	0.0	0.1	0.0				0.0	0.0		0.0	0.4	0.0	0.0	0.0			0.8
NMVOC	0.3	0.1	0.0	0.7	0.1	0.1	0.0	2.6	0.1	0.3	3.6	4.8			0.0	1.6	0.0	3.4	15.8	0.1	1.0	0.1		0.1	4.2
CO	1.0	0.2	0.7	5.3	0.3	0.2	0.1	12.0	0.4	1.2	5.1				0.0	2.8	0.0	1.4	59.6	0.1	2.5	0.8			0.0
PM10	0.3	0.1	0.0	4.3	0.1	0.0	0.0	2.3	0.5	0.9	0.4		4.9	2.6	0.0	3.6	0.0	0.8	53.5	0.0	1.6	0.2	0.2	0.1	0.1
PM2.5	0.2	0.1	0.0	4.4	0.2	0.0	0.0	2.8	0.6	1.1	0.5		3.3	1.8	0.0	4.5	0.0	1.0	65.3	0.0	2.0	0.3	0.0	0.0	0.0
BC	0.1	0.0	0.1	1.5	0.7	0.1	0.0	16.8	3.6	5.8	0.6		2.8	0.5	0.2	5.9	0.0	0.7	45.4	0.0	7.1	1.2	0.2	0.1	0.0

3.4 QA/QC AND VERIFICATION

A complete description of methodological and activity data improvements are documented every year in a QA/QC plan (ISPRA, 2021[b]).

The analysis of data collected from point sources allowed to distribute emissions at local level, for 2015 and previous years, as submitted under the CLTRAP. To illustrate an example, NO_X emissions from point sources are reported in Figure 3.1 for the year 2015. Point sources include public electricity and heat production plants, petroleum refineries, stationary combustion plants (*iron and steel, non-ferrous metals, chemicals, clinker*) and pipeline compressors.

The figure highlights that the most critical industrial areas are distributed in few regions.

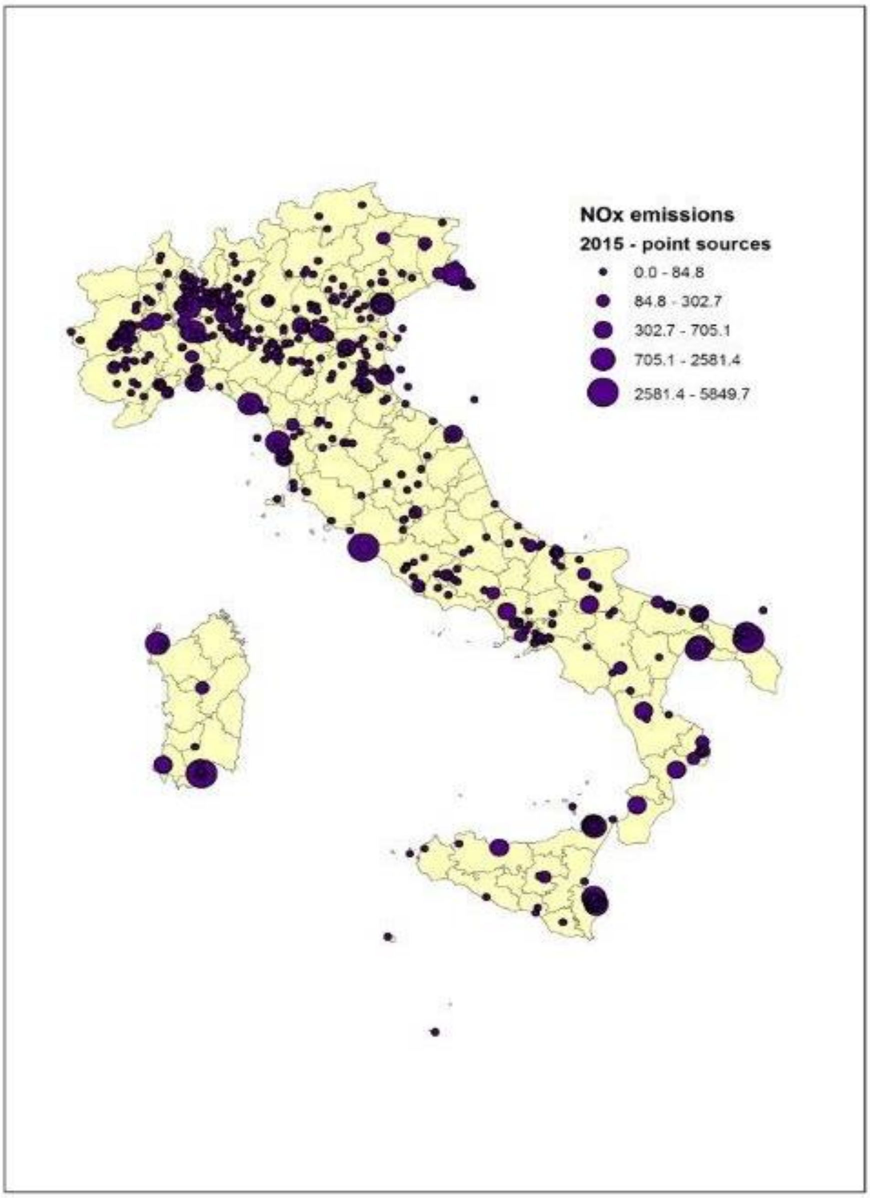


Figure 3.1 *NO_X emissions from point sources in 2015 (t)*

In Figure 3.2, 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 3.2 *NO_X emissions from point sources in 2010 (t)*

Every five years emissions are disaggregated at regional and provincial levels and figures 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. NO_X emissions from *road transport* have been disaggregated at NUTS3 level; the disaggregation related to the year 2015 is reported in Figure 3.3 whereas methodologies are described in the relevant publication (ISPRA, 2009).

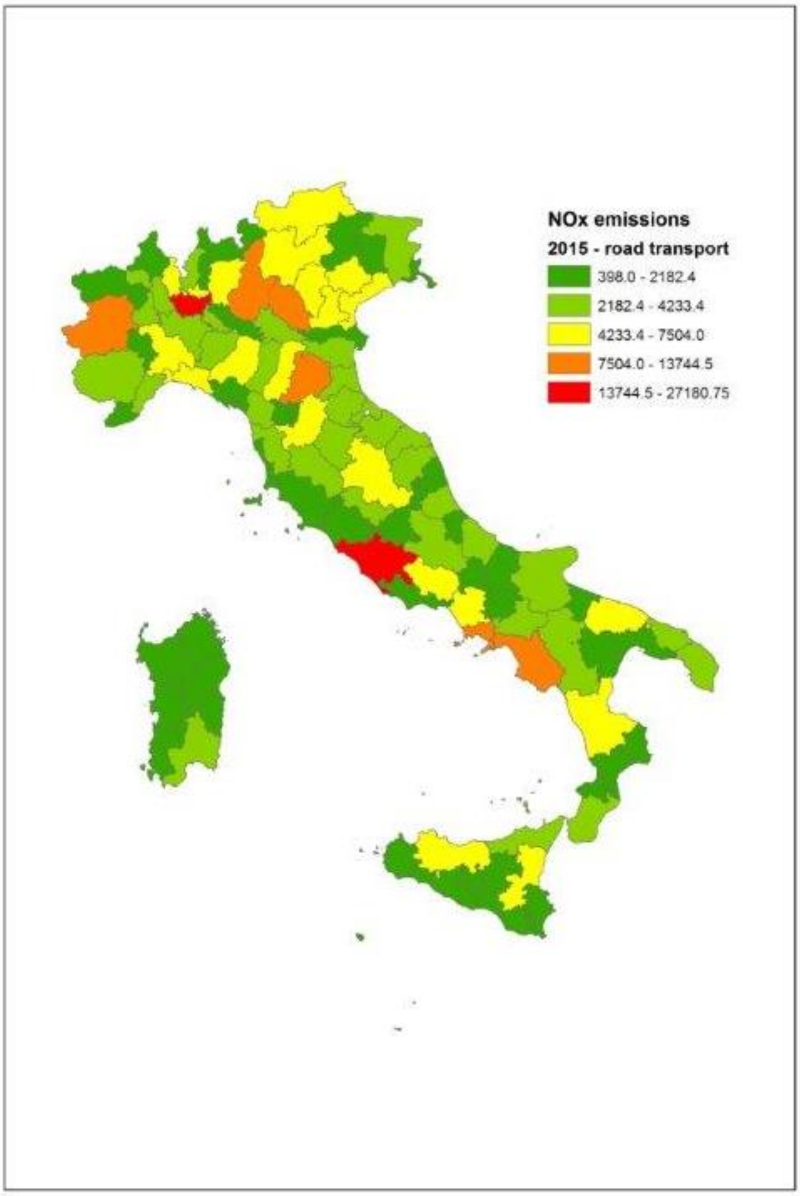


Figure 3.3 *NO_X emissions from road transport in 2015 (t)*

3.5 RECALCULATIONS

In the 2019 submission different recalculations have been performed in the energy sector.

For 1.A.2. category, in particular 1.A.2.a., according to the review, Cd emission factors have been updated since 2003 on the basis of plant level emissions data. Simultaneously, NH_3 emission factors from sinter production have been introduced for the whole time series. Further improvement and recalculations have been occurred for glass production because of the use of E-PRTR data for SO_X, NO_X, As, Se and Zn emissions.

For 1.A.1.c category, and in particular for coke production, fugitive PAH emissions, at first estimated under this category, have been allocated in 1B1b.

For 1.A.3.a category, aviation, there has been an update for the entire time series of the engine classification and for consumption data since 2005 according to data provided by EUROCONTROL for Italy. This has resulted in recalculations for NO_X, SO_X, CO since 2000 and PM, COVNM and PAH for the whole time series.

For road transport (1.A.3.b), the upgraded version of COPERT 5, v. 5.4.36 has been used including a revision of emission factors especially for the new vehicles and the introduction of new categories of vehicles, and resulted in a revision of emission estimates for the whole time series. More details are reported in paragraph 3.8.

For 1.A.3.d maritime activities, activity data from 2012 for recreational craft has been updated and estimated on the basis of the trend of the distribution of two and four strokes engines and their average gasoline fuel consumption.

For 1.A.4, according to the review process, COVNM EF for 1A4ai and NO_X, COVNM and PM2.5 EFs for 1A4bi have been updated on the basis of the 2019 EMEP/EEA Guidebook. More detailed information is reported in paragraph 3.12.

3.6 PLANNED IMPROVEMENTS

Specific improvements are detailed in the 2021 QA/QC plan (ISPRA, 2021[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 Economic Development 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 we plan for the next submission to update as possible renewable fuels and biomass.

Further progress will regard the maritime sector improving the annual estimations on the basis of detailed databases on ships movements.

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, Large Combustion Plants Directive and Environmental Reports, 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) which reports heavy metals emissions measurements by fuel and technology (with or without PM10 abatement technologies) of relevant national plants. From 2001 these emission factors have not been updated. Heavy metals emission data in the EPRTR registry refer only to few not representative plants and are not sufficient to calculate average emission factors. 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 actually used.

A revision of the structure of the energy chapter of the IIR is planned for the next submission introducing specific paragraphs for 1A1 and 1A2 categories.

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

3.7.1 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).

3.7.2 Methodological issues

According to the IPCC Guidelines and Good Practice Guidance (IPCC, 1997; IPCC, 2006; IPCC, 2000) and the EMEP/EEA Guidebook 2016 (EMEP/EEA, 2019), 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 (MSE, 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 (MIT, several years), the Italian civil aviation in the national aviation statistics yearbooks (ENAC/MIT, several years), EUROCONTROL flights data time series 2002–2018 (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, 2019).

EUROCONTROL fuel and emissions time series cover the period 2005-2019, while the number of flights is available since 2002. In this submission an update of classification of engines and their relevant emissions resulted in recalculation of the time series from 2000 affecting in particular NMVOC, PAH and PM emissions, on the basis of new data supplied by EUROCONTROL.

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/MIT, 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/MIT, 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, consumptions are 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.

The fuel split between national and international fuel use in aviation is then supplied to the Ministry of the 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.

Data on domestic and international aircraft movements from 1990 to 2019 are shown in Table 3.2 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 consumptions, both domestic and international, are reported by LTO and cruise in Table 3.3.

Table 3.2 *Aircraft Movement Data (LTO cycles)*

Number of flights	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Domestic flights	172,148	185,220	319,748	350,140	354,520	280,645	277,872	281,498	284,627	288,470
International flights	147,875	198,848	303,608	381,206	406,990	425,410	446,817	462,896	484,764	502,764

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

Table 3.3 *Aviation jet fuel consumptions for domestic and international flights (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
Domestic LTO	111	120	208	233	227	168	166	169	179	180
International LTO	130	175	258	269	296	328	344	355	382	399
Domestic cruise	357	384	654	666	704	526	527	544	563	580
International cruise	1,246	1,688	2,297	2,456	2,534	2,745	2,962	3,230	3,461	3,584

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 (MSE, 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.

3.7.3 Time series and key categories

Emission time series of NO_X, NMVOC, SO_X, TSP, CO, Pb are reported in Table 3.4, Table 3.5, Table 3.6, Table 3.7, Table 3.8 and Table 3.9, 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. Aviation is not a key category.

Table 3.4 *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	2016	2017	2018	2019
					Gg					
1 A 3 a ii (i) Domestic aviation LTO (civil)	1.36	1.47	2.50	2.55	2.71	2.12	2.11	2.14	2.30	2.32
1 A 3 a i (i) International aviation LTO (civil)	1.60	2.16	3.20	3.47	3.99	4.55	4.84	5.02	5.35	5.60
1 A 3 a Civil Aviation (LTO)	**2.97**	**3.62**	**5.70**	**6.02**	**6.70**	**6.68**	**6.96**	**7.16**	**7.65**	**7.92**
1A3 a ii (ii) Domestic aviation cruise (civil)	5.23	5.63	9.43	8.71	10.16	8.09	8.10	8.21	8.51	8.78
1A3a i (ii) International aviation cruise (civil)	18.85	26.83	38.99	36.55	41.02	47.05	50.25	52.04	55.71	59.65
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**	**3.28**	**2.36**	**2.05**	**2.73**

Table 3.5 *Time series of NMVOC (Gg)*

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.12	0.13	0.23	0.25	0.33	0.27	0.26	0.26	0.28	0.30
1 A 3 a i (i) International aviation LTO (civil)	0.15	0.20	0.31	0.39	0.45	0.48	0.49	0.48	0.51	0.52
1 A 3 a Civil Aviation (LTO)	**0.27**	**0.33**	**0.54**	**0.64**	**0.78**	**0.75**	**0.75**	**0.75**	**0.79**	**0.82**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.10	0.10	0.18	0.20	0.37	0.34	0.34	0.34	0.36	0.38
1A3a i (ii) International aviation cruise (civil)	0.25	0.36	0.55	0.69	0.81	0.89	0.92	0.92	0.93	0.94
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**	**0.70**	**0.48**	**0.44**	**0.58**

Table 3.6 *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	2016	2017	2018	2019
					Gg					
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.11	0.12	0.21	0.23	0.23	0.17	0.17	0.17	0.18	0.18
1 A 3 a i (i) International aviation LTO (civil)	0.13	0.17	0.26	0.27	0.30	0.33	0.34	0.35	0.38	0.40
1 A 3 a Civil Aviation (LTO)	**0.24**	**0.29**	**0.47**	**0.50**	**0.52**	**0.50**	**0.51**	**0.52**	**0.56**	**0.58**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.36	0.38	0.65	0.67	0.70	0.53	0.53	0.54	0.56	0.58
1A3a i (ii) International aviation cruise (civil)	1.25	1.78	2.60	2.45	2.65	2.95	3.11	3.24	3.48	3.69
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**	**0.15**	**0.08**	**0.10**	**0.13**

Table 3.7 *Time series of TSP (Gg)*

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.01	0.01	0.02	0.03	0.02	0.02	0.02	0.02	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	0.04	0.04	0.04	0.04
1 A 3 a Civil Aviation (LTO)	**0.03**	**0.04**	**0.06**	**0.07**	**0.06**	**0.05**	**0.05**	**0.05**	**0.06**	**0.06**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.07	0.08	0.13	0.10	0.10	0.07	0.07	0.07	0.08	0.08
1A3a i (ii) International aviation cruise (civil)	0.36	0.52	0.75	0.71	0.83	0.91	0.94	0.94	0.95	0.96
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**	**0.50**	**0.34**	**0.32**	**0.43**

Table 3.8 *Time series of CO (Gg)*

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
1 A 3 a ii (i) Domestic aviation LTO (civil)	1.23	1.33	2.26	2.33	2.28	1.69	1.65	1.71	1.85	1.88
1 A 3 a i (i) International aviation LTO (civil)	1.73	2.32	3.33	2.86	3.00	3.25	3.31	3.35	3.73	3.89
1 A 3 a Civil Aviation (LTO)	**2.96**	**3.64**	**5.59**	**5.19**	**5.28**	**4.94**	**4.95**	**5.06**	**5.57**	**5.77**
1A3 a ii (ii) Domestic aviation cruise (civil)	1.31	1.41	2.43	2.66	3.07	2.35	2.32	2.42	2.51	2.60
1A3a i (ii) International aviation cruise (civil)	2.03	2.89	4.42	5.55	5.74	6.07	6.29	6.45	6.98	7.23
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**	**19.73**	**11.93**	**13.23**	**17.42**

Table 3.9 *Time series of Pb (Mg)*

Source categories for NFR Subsector 1.A.3.a, 1.A.5.b	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.19	0.20	0.35	0.38	0.38	0.30	0.30	0.30	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	0.63	0.65	0.68	0.71
1 A 3 a Civil Aviation (LTO)	**0.39**	**0.48**	**0.77**	**0.91**	**0.96**	**0.90**	**0.93**	**0.96**	**0.99**	**1.02**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.57	0.62	1.06	1.16	1.18	0.93	0.92	0.94	0.95	0.96
1A3a i (ii) International aviation cruise (civil)	2.01	2.86	4.36	5.48	5.85	6.11	6.42	6.65	6.96	7.22
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**16.34**	**4.22**	**1.16**	**0.001**	**NA**	**0.12**	**0.02**	**0.02**	**0.09**	**0.18**

3.7.4 **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 have 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.

3.7.5 **Recalculations**

Recalculations were performed in this submission, due to the update of EUROCONTROL data time series from 2005 to 2018.

3.7.6 **Planned improvements**

Improvements for 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.

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

3.8.1 Overview

The road transport sector contributes to the total national emissions in 2019 as follows: nitrogen oxides emissions for 40.3% of the total; emissions of carbon monoxide for 18.7%, non-methane volatile organic compounds for 11.4%, PM10 and PM2.5, for 11.6% and 10.1%, 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

3.8.2 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, 2019).

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 5.4.36, October 2020) has been used and applied for the whole time series in 2021 submission. COPERT 5 introduces upgrades both from software and methodological point of view respect to the previous model COPERT 4 used (https://www.emisia.com/utilities/copert/versions/). New methodological features have been introduced.
As regards fuel, updates concern: 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 since the previous model version used (in submission 2020, version 5.2.2 had been used) relate: new Emission factors for mopeds 4-stroke; new emission factors for motorcycles; revised evaporation factors for Euro 6d-temp and Euro 6d passenger cars and light commercial vehicles; revised Euro 6 LCV NOx emissions factors; calculation of the fossil fuel fraction in biodiesel; updated emission factors for Euro 5 diesel PCs and LCVs (N1-I) for NOx, VOC and CO, new category added (with software update); updated naming for Euro 6 PCs and LCVs (Euro 6 a/b/c, Euro 6 d-temp, and Euro 6d) and HDVs (Euro VI A/B/C and Euro VI D/E); updated emission factors for Euro 6 PCs (petrol: CO, PM, NOx, VOC; petrol hybrid: PM; LPG and CNG ~ petrol: NOx, VOC; Diesel: CO) and LCVs (petrol: PM; diesel: CO for N1-I only); new vehicle categories and emission factors added (petrol PHEV, diesel PHEV, busses hybrid).
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: http://www.sinanet.isprambiente.it/it/sia-ispra/fetransp.

Data on fuel consumption of gasoline, diesel, liquefied petroleum gas (LPG), natural gas (CNG) and biofuels are those reported in the EUROSTAT energy balance, published on the MSE website (http://dgsaie.mise.gov.it/dgerm/ben.asp); Italian road electricity consumption, introduced in last Copert version, derives 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 due to 2 stroke engines is estimated and reported in 1A3b. All the other national lubricants consumption, including 4 stoke engines, and relevant emissions are reported in 2D3 category.

3.8.2.1 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 2019 (EMEP/EEA, 2019).

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, 2019). 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 2019).

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 1990-2018 inventory used fuel consumption factors expressed as grams of fuel per kilometre for each vehicle type and average speed calculated from the emission functions and speed-coefficients provided by the model COPERT 5, version 5.2.2. 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 (MSE, several years (a)), updated since 2017 according to EUROSTAT methodology (http://dgsaie.mise.gov.it/dgerm/ben.asp).

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 (UP, 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 – 2011; 2012 – 2019 (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. Each year the quantities of natural gas imported or produced in Italy are published on the web by the MSE http://dgerm.sviluppoeconomico.gov.it/dgerm/bilanciogas.asp.

In Italy, as regards biofuels used in road transportation, biodiesel and biogasoline, almost all of the commercial gasoline is still substantially an E0, while the distributed diesel reaches up to 5-7% by volume of biodiesel in diesel fuel (this 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 is in particular used in E85 passenger cars category, representing a minimum percentage out of the total consumption, being equal to 0.40% of the total (gasoline including biogasoline) in 2019. 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.

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 2016, 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 2019.

3.8.2.2 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, 2019).

3.8.2.3 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, 2019).

3.8.2.4 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, 2019).

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, 2019).

3.8.3 **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 (MIT) 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 MIT 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). MIT data are used relating to: the passenger cars (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, 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; 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 (MSE, several years (a)); supplementary information is taken from the Oil Bulletin (MSE, 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.

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;
- Diesel Hybrid passenger cars;
- Gasoline Light Goods Vehicles (Gross Vehicle Weight (GVW) <= 3.5 tonnes);
- Diesel Light Goods Vehicles (Gross Vehicle Weight (GVW) <= 3.5 tonnes);
- Rigid-axle Heavy Goods Vehicles (GVW > 3.5 tonnes);

- Articulated Heavy Goods Vehicles (GVW > 3.5 tonnes);
- Diesel Buses and coaches;
- Diesel Hybrid Buses;
- CNG Buses;
- Mopeds and motorcycles.

In Table 3.10 the historical series of annual consumption data (Mg) for the different fuel types is reported.

Table 3.10 *Annual fuel consumption data (Mg)*

Fuel	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
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	7,297,739	7,089,221	7,286,305	7,353,002
Diesel	15,278,022	14,445,441	17,059,010	22,327,864	21,557,266	21,128,587	21,228,198	20,101,587	20,901,623	20,985,104
LPG	1,342,000	1,478,000	1,422,000	1,029,000	1,214,000	1,654,000	1,598,000	1,667,372	1,614,000	1,653,017
CNG	183,770	216,804	292,214	342,756	610,502	787,148	784,406	740,694	746,783	832,653
Biodiesel	-	44,491	64,723	200,000	1,468,086	1,292,079	1,141,334	1,164,023	1,377,205	1,409,548
Biogasoline	-	-	-	-	142,106	30,420	37,808	38,455	38,238	35,401

Source: ISPRA elaborations on BEN, BP, UP 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 and in 2012 – 2013). 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 three different time phases: 1990 – 1999; 2000 – 2011; 2012 – 2019 (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 MSE http://dgerm.sviluppoeconomico.gov.it/dgerm/bilanciogas.asp).

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 Tables 3.11, 3.12, 3.13 and 3.14 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 MIT data).

Table 3.11 *Passenger Cars technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019

PRE ECE, pre-1973	0.04	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
ECE 15/00-01, 1973-1978	0.10	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ECE 15/02-03, 1978-1984	0.30	0.15	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ECE 15/04, 1985-1992	0.55	0.55	0.28	0.10	0.04	0.03	0.02	0.02	0.02	0.02
PC Euro 1 - 91/441/EEC, from 1/1/93	0.00	0.24	0.27	0.17	0.05	0.02	0.02	0.01	0.01	0.01
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.39	0.32	0.21	0.12	0.10	0.09	0.08	0.07
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.31	0.20	0.13	0.12	0.11	0.10	0.09
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.09	0.44	0.37	0.35	0.33	0.31	0.28
PC Euro 5 - 2007/715/EC, from 1/1/2011	-	-	-	-	0.04	0.25	0.24	0.23	0.21	0.18
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	-	0.06	0.13	0.07	0.09	0.12
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 d-temp from 9/1/2019	-	-	-	-	-	-	-	0.13	0.17	0.22
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

a. Gasoline cars technological evolution

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Conventional, pre-1993	1.00	0.92	0.36	0.06	0.01	0.00	0.00	0.00	0.00	0.00
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.08	0.10	0.03	0.01	0.00	0.00	0.00	0.00	0.00
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.54	0.22	0.05	0.02	0.02	0.01	0.01	0.01
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.57	0.31	0.15	0.14	0.11	0.09	0.08
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.12	0.55	0.41	0.38	0.37	0.30	0.28
PC Euro 5 - 2007/715/EC, from 1/1/2011	-	-	-	-	0.07	0.36	0.32	0.30	0.30	0.28
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	0.00	0.05	0.14	0.07	0.10	0.12
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 d-temp from 9/1/2019	-	-	-	-	-	-	-	0.13	0.19	0.23
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

b. Diesel cars technological evolution

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
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	0.01	0.01	0.01	0.00
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.09	0.19	0.08	0.03	0.03	0.02	0.02	0.02
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.06	0.08	0.05	0.04	0.04	0.03	0.03
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.01	0.75	0.46	0.42	0.38	0.35	0.31
PC Euro 5 - 2007/715/EC, from 1/1/2011	-	-	-	-	0.03	0.36	0.34	0.32	0.30	0.28
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	-	0.08	0.15	0.09	0.11	0.13
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 d-temp from 9/1/2019	-	-	-	-	-	-	-	0.14	0.18	0.23
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

c. Lpg cars technological evolution

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
PC from Conventional to Euro 4	1.00	1.00	1.00	1.00	0.91	0.58	0.54	0.51	0.47	0.44
PC Euro 5 - 2007/715/EC, from 1/1/2011	-	-	-	-	0.09	0.32	0.31	0.31	0.30	0.29
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	-	0.10	0.15	0.10	0.12	0.14
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 d-temp from 9/1/2019	-	-	-	-	-	-	-	0.08	0.10	0.13
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

d. CNG cars technological evolution

	2007	2008	2009	2010	2015	2016	2017	2018	2019
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	1.00	1.00	0.65	0.54	0.22	0.07	0.04	0.03	0.02
PC Euro 5 - 2007/715/EC, from 1/1/2011	-	-	0.35	0.46	0.61	0.42	0.27	0.18	0.11
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 a/b/c	-	-	-	-	0.16	0.51	0.13	0.15	0.15
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 d-temp from 9/1/2019	-	-	-	-	-	-	0.56	0.64	0.72
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

e. Hybrid Gasoline cars technological evolution (from 2007 onwards)									
	2007	**2008**	**2009**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 a/b/c	1.00	1.00	1.00	1.00	1.00	1.00	0.69	0.42	0.11
PC Euro 6 (Since 2007/715/EC, from 9/1/2015) - Euro 6 d-temp from 9/1/2019	-	-	-	-	-	-	0.31	0.58	0.89
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
f. Hybrid Diesel cars technological evolution (from 2007 onwards)									

Source: ISPRA elaborations on MIT and ACI data

Table 3.12 *Light Duty Vehicles technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Conventional, pre 10/1/94	1.00	0.93	0.63	0.35	0.08	0.06	0.06	0.06	0.05	0.03
LCV Euro 1 - 93/59/EEC, from 10/1/94	-	0.07	0.22	0.17	0.10	0.04	0.04	0.04	0.03	0.02
LCV Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.15	0.15	0.30	0.15	0.15	0.14	0.12	0.06
LCV Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.31	0.26	0.19	0.19	0.18	0.15	0.11
LCV Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.25	0.32	0.32	0.32	0.28	0.24
LCV Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.004	0.22	0.20	0.17	0.19	0.17
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 a/b/c	-	-	-	-	-	0.02	0.05	0.09	0.06	0.11
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 d-temp	-	-	-	-	-	-	-	-	0.11	0.25
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
a. Gasoline Light Commercial Vehicles technological evolution										
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Conventional, pre 10/1/94	1.00	0.92	0.55	0.23	0.07	0.02	0.02	0.02	0.01	0.01
LCV Euro 1 - 93/59/EEC, from 10/1/94	-	0.08	0.21	0.11	0.05	0.02	0.02	0.01	0.01	0.01
LCV Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.23	0.20	0.18	0.07	0.06	0.04	0.03	0.02
LCV Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.45	0.34	0.21	0.18	0.12	0.09	0.07
LCV Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.34	0.33	0.29	0.27	0.23	0.18
LCV Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.01	0.35	0.37	0.35	0.34	0.33
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 a/b/c	-	-	-	-	0.00	0.01	0.07	0.19	0.12	0.17
LCV Euro 6 (Since 2007/715/EC, from 9/1/2016) - Euro 6 d-temp	-	-	-	-	-	-	-	-	0.16	0.22
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
b. Diesel Light Commercial Vehicles technological evolution										

Source: ISPRA elaborations on MIT and ACI data

Table 3.13 *Heavy Duty Trucks and Buses technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Conventional, pre 10/1/93	1.00	0.90	0.67	0.39	0.20	0.02	0.02	0.02	0.02	0.01
HDT Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.10	0.10	0.06	0.04	0.01	0.01	0.01	0.01	0.01
HDT Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.22	0.27	0.15	0.08	0.07	0.06	0.05	0.05
HDT Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.27	0.36	0.34	0.31	0.28	0.25	0.22
HDT Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.07	0.10	0.09	0.08	0.08	0.07
HDT Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.18	0.38	0.37	0.36	0.34	0.33
HDT Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI A/B/C	-	-	-	-	-	0.07	0.13	0.19	0.15	0.18
HDT Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI D/E	-	-	-	-	-	-	-	-	0.10	0.13
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
a. Heavy Duty Trucks technological evolution										
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Conventional, pre 10/1/93	1.00	0.93	0.65	0.34	0.13	0.01	0.01	0.01	0.01	0.01
Buses Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.07	0.07	0.08	0.04	0.01	0.01	0.01	0.00	0.01

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Buses Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.28	0.32	0.27	0.14	0.13	0.11	0.08	0.08
Buses Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.26	0.34	0.38	0.35	0.32	0.28	0.25
Buses Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.12	0.13	0.12	0.11	0.11	0.11
Buses Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.11	0.28	0.28	0.29	0.27	0.27
Buses Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI A/B/C	-	-	-	-	-	0.05	0.10	0.16	0.13	0.15
Buses Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI D/E	-	-	-	-	-	-	-	-	0.11	0.13
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	2016	2017	2018	2019
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	0.00	0.00	0.00	0.00	0.00	0.00
Urban CNG Buses Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.89	0.20	0.10	0.05	0.04	0.04	0.03	0.03
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	0.07	0.07	0.06	0.06
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); Urban CNG Buses Euro VI – EC 595/2009, from 12/31/2013	-	-	-	-	0.81	0.88	0.88	0.89	0.90	0.91
Total	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

	2007	2008	2009	2010	2015	2016	2017	2018	2019
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	1.00	1.00	0.27	0.11
Buses Euro VI (Since 2009/595/EC, from 12/31/2013) - Euro VI D/E	-	-	-	-	-	-	-	0.73	0.89
Total	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

Source: ISPRA elaborations on MIT and ACI data

Table 3.14 *Mopeds and motorcycles technological evolution***:** *circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Mopeds and motorcycles - Conventional	1.00	1.00	0.86	0.43	0.18	0.11	0.10	0.11	0.11	0.11
Mopeds and motorcycles - Euro 1	-	-	0.14	0.30	0.20	0.13	0.13	0.13	0.11	0.11
Mopeds and motorcycles - Euro 2	-	-	-	0.22	0.35	0.34	0.33	0.31	0.30	0.23
Mopeds and motorcycles - Euro 3	-	-	-	0.04	0.27	0.42	0.43	0.41	0.39	0.41
Mopeds and motorcycles - Euro 4	-	-	-	-	-	-	0.01	0.05	0.10	0.14
Mopeds and motorcycles - Euro 5	-	-	-	-	-	-	0.00	0.00	0.00	0.0002
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: ISPRA elaborations on ANCMA, ACI and MIT data

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, see Table 3.15, 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 3.15 *Evolution of fleet consistency and mileage*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
All passenger vehicles (including moto), total mileage (10^9 veh-km/y)	350	412	455	453	450	444	445	447	441	443
Car fleet (10^6)	27	30	32	34	36	37	38	38	39	40
Moto, total mileage (10^9 veh-km/y)	30	41	42	42	36	33	31	28	27	28
Moto fleet (10^6)	7	7	9	9	9	10	10	10	10	10
Goods transport, total mileage (10^9 veh-km/y)	69	76	83	104	83	62	60	52	65	65
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.

3.8.4 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, on one side, and of the introduction of advanced technologies limiting emissions in modern vehicles and of the economic crisis in recent years, on the other side.

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 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 are 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. In Table 3.16 the list of key categories by pollutant identified for road transport in 2019, 1990 and at trend assessment is reported.

Table 3.16 *List of key categories for pollutant in the road transport in 2019, 1990 and in the trend*

	Key categories in 2019	*Key categories in 1990*	*Key categories in trend*
SO_X		1A3bi	
NO_X	1A3bi 1A3bii 1A3biii	1A3bi 1A3bii 1A3biii	1A3bi 1A3bii 1A3biii
NMVOC	1A3bi 1A3biv 1A3bv	1A3bi 1A3biv 1A3bv	1A3bi 1A3biv 1A3bv
NH_3			1A3bi
CO	1A3bi 1A3biv	1A3bi 1A3biv	1A3bi
PM_{10}	1 A 3 bi 1A3bvi 1A3bvii	1A3bi 1A3bii 1A3biii 1A3bvi	1A3bi 1A3bii 1A3biii 1A3bvi
$PM_{2.5}$	1 A 3 bi 1A3bvi	1A3bi 1A3bii 1A3biii 1A3bvi	1A3bi 1A3bii 1A3biii
BC	1A3bi 1A3biii	1A3bi 1A3bii 1A3biii	1A3bi 1A3bii 1A3biii
Pb	1A3bvi	1A3bi 1A3biv	1A3bi
Cd	1A3bi		1A3bi

Source: ISPRA elaborations

In 2019 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 -74.6%. 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.

In 2019, emissions of nitrogen oxides (Table 3.17) 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 3.17 *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	2016	2017	2018	2019
			Gg							
1.A.3.b.i Passenger cars	590.92	628.53	388.63	240.19	176.85	167.28	162.62	144.54	132.96	127.10
1.A.3.b.ii Light-duty vehicles	60.60	69.51	71.19	75.14	53.25	41.04	40.68	34.82	41.55	41.20
1.A.3.b.iii Heavy-duty vehicles including buses	340.33	336.12	311.36	306.67	186.73	114.80	106.10	86.53	88.90	81.35
1.A.3.b.iv Mopeds and motorcycles	4.29	5.55	6.07	6.85	5.08	4.29	3.91	3.46	3.19	3.07
Total emissions	**996.15**	**1,039.71**	**777.25**	**628.85**	**421.91**	**327.41**	**313.31**	**269.36**	**266.60**	**252.72**

Source: ISPRA elaborations

As regards non methane volatile organic compounds, emissions from passenger cars, mopeds and motorcycles and gasoline evaporation are key categories in 2019, 1990 and in trend.

Despite the decline of about -86.7% since 1990 of emissions of non methane volatile organic compounds from this category, road transport (Table 3.18) 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 9.9 million vehicles in 2019) that uses gasoline and it is increased of about 49.5% since 1990 (this fleet not completely complies with strict VOC emissions controls).

Table 3.18 *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	2016	2017	2018	2019
			Gg							
1.A.3.b.i Passenger cars	430.45	467.18	261.44	122.45	48.33	28.29	24.93	23.89	22.06	23.23
1.A.3.b.ii Light-duty vehicles	15.56	18.47	13.91	11.52	5.77	2.09	1.78	1.25	1.30	0.91
1.A.3.b.iii Heavy-duty vehicles including buses	26.35	25.19	20.52	17.34	8.31	3.51	3.23	2.61	2.67	2.44
1.A.3.b.iv Mopeds and motorcycles	175.51	248.77	225.42	152.44	76.97	46.77	42.52	38.72	35.61	32.19
1.A.3.b.v Gasoline evaporation	119.22	119.10	87.87	55.55	45.28	46.03	44.87	46.07	45.52	43.31
Total emissions	**767.08**	**878.71**	**609.16**	**359.30**	**184.66**	**126.69**	**117.34**	**112.55**	**107.17**	**102.08**

Source: ISPRA elaborations

Carbon monoxide emissions from passenger cars and mopeds and motorcycles are key categories in 2019 and 1990; passenger cars are also key category in trend. The time series of CO emissions is reported in Table 3.19.

Table 3.19 *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	2016	2017	2018	2019
			Gg							
1.A.3.b.i Passenger cars	4,124.60	4,151.75	2,137.75	1,078.91	478.10	290.88	260.25	250.60	237.50	247.81
1.A.3.b.ii Light-duty vehicles	175.06	207.29	140.17	97.63	45.27	17.98	15.44	12.54	12.68	8.18
1.A.3.b.iii Heavy-duty vehicles including buses	81.44	79.76	70.23	70.20	46.66	33.30	31.07	25.94	26.98	25.13
1.A.3.b.iv Mopeds and motorcycles	493.42	667.33	625.65	434.49	206.23	136.81	123.67	113.50	107.70	105.36
Total emissions	**4,874.52**	**5,106.13**	**2,973.80**	**1,681.22**	**776.25**	**478.98**	**430.42**	**402.58**	**384.85**	**386.48**

Source: ISPRA elaborations

A strong contribution to total emissions is given by gasoline vehicles (about 79.0% in 2019, although since 1990 a decrease of about -93.2% is observed); since 1990 to 2019 a general decrease, of about -92.1%, is observed.

Emissions of PM10 (Table 3.20) 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 passenger cars, road vehicle tyre and brake wear and emissions from road surface wear are key categories in 2019; 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 3.21), emissions from passenger cars, light-duty vehicles, heavy-duty vehicles including buses are key categories in 1990 and in trend, road vehicle tyre and brake wear is also key category in 1990; while emissions from passenger cars and road vehicle tyre and brake wear are key categories in 2019.

Table 3.20 *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	2016	2017	2018	2019
			Gg							
1.A.3.b.i Passenger cars	19.27	14.13	12.31	9.81	8.31	5.86	5.40	5.04	4.05	3.96
1.A.3.b.ii Light-duty vehicles	10.36	11.51	10.27	8.84	4.66	1.69	1.43	1.00	1.07	0.85
1.A.3.b.iii Heavy-duty vehicles including buses	13.56	13.30	10.74	9.09	4.62	2.24	2.05	1.67	1.69	1.53
1.A.3.b.iv Mopeds and motorcycles	3.70	5.26	4.86	3.16	1.47	0.88	0.80	0.74	0.70	0.68
1 A 3 b vi Road Transport:, Automobile tyre and brake wear	7.68	8.71	9.40	10.13	9.47	9.27	8.63	8.10	8.39	8.41
1.A.3.b.vii Road transport: Automobile road abrasion	4.18	4.68	4.99	5.29	4.81	4.48	4.48	4.36	4.51	4.53
Total emissions	**58.74**	**57.58**	**52.57**	**46.32**	**33.34**	**24.41**	**22.79**	**20.91**	**20.42**	**19.96**

Source: ISPRA elaborations

Table 3.21 *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	2016	2017	2018	2019
			Gg							
1.A.3.b.i Passenger cars	19.27	14.13	12.31	9.81	8.31	5.86	5.40	5.04	4.05	3.96
1.A.3.b.ii Light-duty vehicles	10.36	11.51	10.27	8.84	4.66	1.69	1.43	1.00	1.07	0.85
1.A.3.b.iii Heavy-duty vehicles including buses	13.56	13.30	10.74	9.09	4.62	2.24	2.05	1.67	1.69	1.53
1.A.3.b.iv Mopeds and motorcycles	3.70	5.26	4.86	3.16	1.47	0.88	0.80	0.74	0.70	0.68
1 A 3 b vi Road Transport: Automobile tyre and brake wear	4.17	4.74	5.13	5.52	5.17	5.03	4.73	4.47	4.63	4.64
1.A.3.b.vii Road transport: Automobile road abrasion	2.26	2.52	2.69	2.86	2.60	2.42	2.42	2.36	2.44	2.45
Total emissions	**53.31**	**51.46**	**46.01**	**39.27**	**26.82**	**18.12**	**16.83**	**15.27**	**14.58**	**14.11**

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 -66.0% and -73.5%; 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 2019 about 75.5% and 78.3% out of the total for PM10 and PM2.5 respectively.

Emissions of black carbon are reported in Table 3.22. Emissions from passenger cars and heavy-duty trucks including buses are key categories in 2019; emissions from passenger cars, light-duty vehicles and heavy-duty trucks including buses are key categories in 1990 and in trend.

The emissions trend is generally decreasing (-77.5% since 1990). The main contribution to total emissions is given by diesel vehicles, in 2019 equal to 93.9% out of the total. Despite of the decrease, road transport is the second source of emissions (the main source is non industrial combustion) at national level in 2019 (30.1%).

Table 3.22 *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	2016	2017	2018	2019
			Gg							
1.A.3.b.i Passenger cars	10.39	7.60	7.47	7.28	6.76	4.65	4.27	3.97	3.11	3.02
1.A.3.b.ii Light-duty vehicles	5.69	6.37	6.06	5.92	3.49	1.34	1.13	0.78	0.82	0.65

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
1.A.3.b.iii Heavy-duty vehicles including buses	6.78	6.79	5.71	5.17	2.82	1.53	1.40	1.14	1.15	1.04
1.A.3.b.iv Mopeds and motorcycles	0.66	0.95	0.87	0.55	0.25	0.15	0.14	0.13	0.12	0.12
1A3bvi Road transport: Automobile tyre and brake wear	0.44	0.50	0.54	0.58	0.55	0.53	0.51	0.48	0.50	0.50
1.A.3.b.viiRoad transport: Automobile road abrasion	0.09	0.10	0.11	0.11	0.10	0.09	0.09	0.09	0.10	0.10
Total emissions	**24.04**	**22.30**	**20.76**	**19.62**	**13.98**	**8.29**	**7.54**	**6.59**	**5.80**	**5.42**

Source: ISPRA elaborations

Emissions of cadmium are reported in Table3.23. Cadmium emissions from passenger cars are key categories in 2019 and in trend.
Emissions show a decrease since 1990 of about -1.0%, representing in 2019 the 9.1% of the national total. In 2019 most of the emissions derive from passenger cars (66.6%); non exhaust emissions from automobile tyre and brake wear are equal to 12.6% of the total.

Table 3.23 *Time series of Cadmium emissions in road transport (Gg)*

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
			Mg							
1.A.3.b.i Passenger cars	0.21	0.24	0.27	0.26	0.26	0.27	0.27	0.27	0.27	0.27
1.A.3.b.ii Light-duty vehicles	0.02	0.03	0.03	0.04	0.04	0.03	0.02	0.02	0.03	0.03
1.A.3.b.iii Heavy-duty vehicles including buses	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
1.A.3.b.iv Mopeds and motorcycles	0.09	0.13	0.13	0.11	0.08	0.05	0.05	0.04	0.04	0.03
1.A.3.b.vi Road transport: Automobile tyre and brake wear	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05
Total emissions	**0.41**	**0.49**	**0.52**	**0.51**	**0.46**	**0.43**	**0.42**	**0.40**	**0.41**	**0.40**

Source: ISPRA elaborations

Emissions of SO_X, NH_3 and Pb are shown in Table 3.24; SO_X, NH_3 are not key categories in 2019; Pb emissions from road vehicle tyre and brake wear are key category in 2019, Pb emissions from passenger cars and from mopeds and motorcycles are key categories in 1990, Pb emissions from passenger cars are key categories in trend; emissions of SO_X from passenger cars is key category in 1990; emissions of NH_3 from passenger cars are key categories in trend. In 2019 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 3.5% since 1990); total Pb emissions decrease of -99.7% since 1990, representing in 2019 about 5.3% of the national total. SO_X emissions decrease by -99.7%, representing 0.3% of the total in 2019. Emissions of NH_3, despite the strong increase since 1990, in 2019 account for just 1.5% out of the total.

Table 3.24 *Time series of sulphur oxides, ammonia and lead emissions in road transport*

SO_X , NH_3, Pb Total Emissions for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
SO_X (Gg)	129.29	71.27	11.86	2.19	0.39	0.34	0.37	0.38	0.37	0.35
NH_3 (Gg)	0.79	5.08	19.85	14.87	9.29	5.74	5.39	5.08	5.29	5.20
Pb (Mg)	3,782.34	1,617.32	690.00	13.22	12.30	12.19	10.99	10.14	10.45	10.46

Source: ISPRA elaborations

3.8.5 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.

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, Land and Sea, 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.

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).

3.8.6 **Recalculation**

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

In 2021 submission the historical series has been revised mainly as a result of the upgrade of Copert model version used (from version 5.2.2 in last submission to 5.4.36 in submission 2021), which resulted in various methodological updates, the main ones being: new Emission factors for mopeds 4-stroke; new emission factors for motorcycles; revised evaporation factors for Euro 6d-temp and Euro 6d passenger cars and light commercial vehicles; revised Euro 6 LCV NOx emissions factors; calculation of the fossil fuel fraction in biodiesel; updated emission factors for Euro 5 diesel PCs and LCVs (N1-I) for NOx, VOC and CO, new category added (with software update); updated naming for Euro 6 PCs and LCVs (Euro 6 a/b/c, Euro 6 d-temp, and Euro 6d) and HDVs (Euro VI A/B/C and Euro VI D/E); updated emission factors for Euro 6 PCs (petrol: CO, PM, NOx, VOC; petrol hybrid: PM; LPG and CNG ~ petrol: NOx, VOC; Diesel: CO) and LCVs (petrol: PM; diesel: CO for N1-I only); new vehicle categories and emission factors added (petrol PHEV, diesel PHEV, busses hybrid).

Differences between the output results of the two Copert versions derive also from fixed bugs or corrections of values in the model, for instance the value of As emission from tyre and brake wear in version 5.4.36 is much higher than in version 5.2.2, and in version 5.4.36 the emission value of Hg from automobile tyre and brake wear is absent (however very low in version 5.2.2).

The change of the version was also the occasion for a general revision of input data and parameters.

In particular, as regards consumptions, in 2006 and 2007, biodiesel consumptions values have been revised upwards according to a different Ministry of Economic Development data source so that road transport consumptions historical series is more consistent than previously; natural gas consumption values have been updated according to revisions applied to parameters considered in the calculation.

As regards fleet data, motorcycles 2-stroke >50 cm³ fleet has been estimated, on the basis of Ministry of Transport data, also for the years 1990 – 2004 (until last submission for these years it was accounted in motorcycles 4-stroke <250 cm³ category); mopeds circulating fleet estimation has been revised on the basis of a joint assessment of ANCMA statistics and Ministry of Transport data, in order to address some inconsistencies related to old and not classified vehicles in Ministry of Transport database (revisions relate years since 2001: updated estimated values for the real circulating fleet result lower for the years from 2001 to 2011 and higher since 2012, respect to last submission values).

The highway driving share has been revised in order to better adhere to national transport statistics, in particular as regards freight transport.

Data and information about vehicles radiations, supplied from Ministry of Transport for this submission, have been applied in the detail of the vehicle category and of the year for the whole historical series, resulting in a reduction of the real circulating fleet values estimation in the past years.

3.8.7 **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.

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

The electricity used by the railways for electric traction is supplied from 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 (MSE, several years [a]), updated since 2018 according to EUROSTAT methodology (http://dgsaie.mise.gov.it/dgerm/ben.asp), and on the methodology Tier1, and emission factors from the EMEP/EEA Emission Inventory Guidebook 2019 (EMEP/EEA, 2019).

Fuel consumption data are collected by the Ministry of Economic Development, responsible of 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 the use of these railways. Because of low values, emissions from railways do not represent a key category. In Table 3.25, 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. 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).

Table 3.25 *Consumptions and emissions time series in railways*

Consumptions and Emissions for NFR Subsector 1.A.3.c	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Diesel Consumption (TJ)	8,370.25	8,199.43	5,850.63	4,142.42	2,690.44	939.52	640.58	1,409.28	1,879.04	1,836.33
Emissions from diesel trains (Gg)										
NO_X	10.27	10.06	7.18	5.08	3.24	1.00	0.67	1.43	1.85	1.75
NMVOC	0.91	0.89	0.64	0.45	0.29	0.09	0.06	0.13	0.18	0.17
SO_X	1.18	0.77	0.08	0.01	0.001	0.0003	0.0002	0.001	0.001	0.001
NH_3	0.001	0.001	0.001	0.001	0.0004	0.0002	0.0001	0.0002	0.0003	0.0003
PM2.5	0.28	0.28	0.20	0.14	0.08	0.03	0.02	0.04	0.05	0.05
PM10	0.28	0.28	0.20	0.14	0.09	0.03	0.02	0.04	0.05	0.05
TSP	0.29	0.28	0.20	0.14	0.09	0.03	0.02	0.04	0.05	0.05
BC	0.18	0.18	0.13	0.09	0.06	0.02	0.01	0.03	0.03	0.03
CO	2.10	2.05	1.47	1.04	0.67	0.24	0.16	0.35	0.47	0.46

Source: ISPRA elaborations

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 fuelled with biomass nowadays instead of coal. Nor biomass or coal are reported in the energy balance for railways activities. Anyway this possible source of emission could be considered insignificant.

No recalculation occurred in this submission.

No specific improvements are planned for the next submission.

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

3.10.1 Overview

This source category includes all emissions from fuels delivered to water-borne navigation. Emissions decreased from 1990 to 2019, because of the reduction in fuel consumed in harbour and navigation activities; the number of movements, showing an increase since 1990, reverses the trend in recent years. National navigation is a key category in 2019 with respect to emissions of SO_X, NO_X, PM10, PM2.5 and BC.

3.10.2 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, 2019). In particular, 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 harbour activities; emissions from international navigation are also estimated and included as memo item but not included in national totals (EMEP/EEA, 2019). 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 comprise 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 (MSE, 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 (MSE, several years (a));
- Data on annual arrivals and departures of domestic and international shipping calling at Italian harbours 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 (MIT, several years).

As for emission and consumption factors, figures are derived by the EMEP/EEA guidebook (EMEP/EEA, 2019), both for recreational and harbour activities and national cruise, taking into account national specificities. These specificities derive from the results of a national study which, taking into account 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)) on the basis of 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 harbour 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 in order to consider most recent trends in the maritime sector both in terms of modelling between domestic and international consumptions and improvements of operational activities in harbour (TECHNE, 2009). On the basis of 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 takes into account origin-destination ship movements matrices as well as technical information on the ships, as engine size, gross tonnage of ships and operational times in harbours. On the basis of sample information, estimates have been carried out at national level for the relevant years considering the official statistics of the maritime sector.

In general, to carry out national estimates of greenhouse gases and other pollutants in the Italian inventory for harbour 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, consumptions are 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 in particular 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 harbours 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 harbour) and from 2010, 2% in domestic waters and 1% in harbour. For inland waterways, which include the navigation on the Po river and ferry-boats in the Venice lagoon, the same legislation is applied.

The composition of the fleet of gasoline fuelled 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 takes into account 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 engine equipped and 10% four stroke while in the last year four strokes 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 2019 EMEP/EEA Guidebook (EMEP/EEA, 2019).

3.10.3 Time series and key categories

In Table 3.26 the list of key categories by pollutant identified for navigation in 2019, 1990 and at trend assessment is reported. Navigation is, in 2019, key category for many pollutants: SO_X, NO_X, PM10, PM2.5, BC; furthermore, it is a key driver of the SO_X and NO_X trend.

Table 3.26 *List of key categories for pollutant in navigation in 2018, 1990 and in the trend*

	Key categories in 2018	*Key categories in 1990*	*Key categories in trend*
SOx	1A3dii	1A3dii	1A3dii
NOx	1A3dii	1A3dii	1A3dii
PM10	1A3dii	1A3dii	
PM2.5	1A3dii	1A3dii	
BC	1A3dii		

Source: ISPRA elaborations

Estimates of fuel consumption for domestic use, in the national harbours or for travel within two Italian destinations, and bunker fuels used for international travels are reported in Table 3.27.

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 harbour activities and a reduction in ship domestic movements inverted the tendency in the last years.

Table 3.27 *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**	**2016**	**2017**	**2018**	**2019**
Gasoline for recreational craft (Gg)	182.12	210.14	213.14	199.13	169.11	96.82	95.95	94.98	93.99	92.98
Diesel oil for inland waterways (Gg)	19.81	22.74	20.21	24.76	18.19	27.45	26.92	28.69	27.63	24.02
Fuels used in domestic cruise navigation (Gg)	778.06	706.38	811.37	739.97	725.35	545.35	542.40	545.99	577.86	639.98
Fuel in harbours (dom+int ships) (Gg)	748.46	692.95	818.48	758.89	743.90	559.30	556.27	559.95	592.64	656.34
Fuel in international Bunkers (Gg)	1,402.72	1,287.30	1,306.31	2,147.25	2,174.64	1,741.79	2,107.25	2,240.41	2,242.54	2,033.84
Emissions from National Navigation (Gg)										
Emissions of NOx	95.55	87.97	102.48	94.94	93.28	70.65	70.30	70.86	74.84	82.48
Emissions of NMVOC	46.11	52.42	50.17	43.28	31.82	16.32	15.72	15.10	14.60	14.21
Emissions of SOx	77.94	70.31	81.49	49.73	28.38	21.34	21.22	21.36	22.61	25.04
Emissions of PM2.5	9.30	8.83	9.61	8.90	7.86	5.55	5.49	5.49	5.72	6.21
Emissions of PM10	9.33	8.86	9.65	8.94	7.89	5.58	5.51	5.51	5.75	6.24
Emissions of BC	1.33	1.25	1.40	1.31	1.23	0.93	0.93	0.93	0.98	1.06
Emissions of CO	102.27	115.57	124.77	122.86	109.42	62.22	60.81	59.39	58.21	57.30

Source: ISPRA elaborations

3.10.4 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 analysed in details 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 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, Land and Sea, and air quality model experts. Top-down and bottom-up approaches have been compared with the aim to identify 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.

3.10.5 Recalculations

A recalculation occurred for recreational craft emissions from 2012, for all the pollutant, due to the update of the time series of recreational craft gasoline fuel consumption reconstructed, because of a lack of information on the national energy statistics for the last years, on the basis of the percentage of gasoline four stroke fleet on the total and average fuel consumption of two and four stroke engines. Moreover, the total fleet of recreational craft for 2018 has been updated as well as the number of ships arrived for the same year.

3.10.6 Planned improvements

Further improvements will include a verification of activity data on ship movements and emission estimates with regional environmental agencies, especially with those more affected by maritime pollution.

3.11 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 on the basis of natural gas fuel consumption used for the compressors and the relevant emission factors. The amount of fuel consumption is estimated on the basis of 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 the 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 taken into account to estimate air pollutants, especially SO_X, NO_X, CO and PM10.

Regarding QA/QC, fuel consumptions reported by the national operators for this activity are 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 consumptions by kilometre are calculated and used for verification of data collected by the operators. Energy consumptions and emissions by kilometre 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.

No recalculations occurred with respect the previous submission.

In Table 3.28, nitrogen oxides, non-methane volatile organic compounds, sulphur oxides, particulate and carbon monoxide emissions (Gg) are reported.

Table 3.28 *Emissions from pipeline compressors (Gg)*

Emissions for NFR Subsector 1.A.3.e	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
NOx	2.89	4.18	2.96	2.37	1.71	0.36	0.46	0.55	0.60	0.43
NMVOC	0.02	0.03	0.04	0.04	0.05	0.02	0.03	0.03	0.03	0.03
SOx	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.005
PM10	0.02	0.03	0.05	0.03	0.03	0.02	0.02	0.02	0.02	0.02
CO	1.26	1.38	1.03	0.60	0.61	0.23	0.30	0.35	0.21	0.18

Source: ISPRA elaborations

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

3.12.1 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 3.29 the list of categories for small combustion and off road vehicles identified as key categories by pollutant for 2019, 1990 and in the trend is reported.

Table 3.29 *List of key categories by pollutant in the civil sector in 2019, 1990 and trend*

	Key categories in 2019			*Key categories in 1990*		*Key categories in trend*		
SO_X	1 A 4 b 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 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			
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		

3.12.2 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 wastes used in electricity generation as well as biogas recovered in landfills and wastewater treatment plant. 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 of 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 (MSE, 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 Economic Development 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. The time series of fuel consumption for the civil sector are reported in Table 3.30.

Table 3.30 *Time series of fuel consumption for the civil sector*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					TJ					
1 A 4 a i Commercial / Institutional: Stationary plants	206,427	247,440	306,051	419,476	488,985	400,538	402,552	402,542	429,231	424,055
1 A 4 b i Residential: Stationary plants	1,002,131	1,003,620	1,036,905	1,172,315	1,222,518	1,078,526	1,070,424	1,093,224	1,044,891	1,019,507
1 A 4 b ii Residential: Household and gardening (mobile)	466	571	374	154	66	57	35	35	35	35
1 A 4 c i Agriculture/Forestry/Fishing: Stationary	9,688	9,487	8,146	10,172	8,829	8,237	6,406	6,569	6,649	6,923
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	83,116	83,543	88,497	89,133
1A 4 c iii Agriculture/Forestry/Fishing: National Fishing	8,413	9,651	8,584	10,464	7,731	6,194	6,918	6,662	7,046	7,175
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	7,183	4,531	4,754	6,317

3.12.3 Methodological issues

The Tier 2 methodology is applied to the whole category. Emission 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 2019 and in trend for NO_X, NMVOC and HCB emissions as well as for cadmium and Dioxin in 1990, and SO_X and dioxins in trend analysis. Most of these pollutants are due prevalently to emissions from waste incineration with energy recovery (more than 90% for HCB, PCB and HMs with the exception of Hg (73%) and Ni (84%), around 90% for NMVOC and SO_X and 27% of the total for NO_X). 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 7.3. 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 recover 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, to 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 natural gas for NO_X while trend of SO_X are 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 3.12.3.2 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 3.12.3.1. For the other fuels the default emission factors of EMEP/CORINAIR 2007 Guidebook have been used; it is planned to update these emission factors with those reported in the 2019 EMEP/EEA Guidebook and, according to the last review process, the update of EFs started from the current report with COVNM emissions. For gasoil, biogas and gasoline different emission factors are used for stationary engines and boilers.
Concerning the other pollutants, PM2.5 emissions from wood and waste account for around 80% of the total 1.A.4.a i category; the other main fuel used for this category is biogas from landfills and waste water treatment energy recovery, which account for around 10% of PM2.5 emissions of this category; an emission factor equal to 10 g/GJ is used. The other fuels have been estimated with EMEP/CORINAIR 2007 emission factors. For NO_X, in addition to waste fuel, see methodology in the waste chapter and in particular emission factors reported in Table 7.3, and natural gas, as described in the following paragraph 3.12.3.1, the other main fuel driving emission estimates is biogas from landfills and waste water treatment energy recovery, accounting for 45% of NO_X emissions of this category in 2019, 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. These fuels plus wood that is also estimated with a Tier 2 account for more than 72% 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 2019 for SO_X, NO_X, NMVOC, CO, PM10, PM2.5, BC, Cd, PAH, Dioxin, HCB and PCB emissions. Most of these pollutants are also key in 1990 and for trend analysis. Most of these pollutants are due prevalently to emissions from wood combustion (more than 99% for PM, BC, PAH, Se, Zn, HCB and PCB emissions, 98% for dioxins and Pb, more than 90% for other HMs, as well as for CO and NMVOC, 99% for both, around 65% for SO_X and 43% of the total for NO_X) for which a Tier 2 is applied. Methodology and emission factors are described in paragraph 3.12.3.2.
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. More than 50% of the total emissions are due to the combustion of natural gas; methodology and country specific emission factors are described in the following paragraph 3.12.3.1. Biomass combustion accounts for around 40% of the total and methodology and country specific emission factors are also available in paragraph 3.12.3.2. For the other fuels, the default EMEP/CORINAIR 2007 Guidebook values have been used. In particular for liquid fuels (gasoil, kerosene and LPG) a default equal to 50 g/GJ is used. All these fuels cover more than 99% of total category emissions. According to the last review process, 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 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. 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 category 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.

3.12.3.1 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, 2016).

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 the 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 3.31 the time series of NO_X average emission factors for the relevant categories is reported.

Table 3.31 *Time series of NO_X emissions factor for the civil sector*

EF NOx	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
			g/Gj							
1 A 4 a i Commercial / Institutional: Stationary	50	48.5	40.2	35.2	32.4	30.3	29.9	29.5	29.1	28.8
1 A 4 b i Residential: Stationary plants	50	48.1	38.2	31.7	31.1	30.5	30.3	29.9	29.6	29.6

3.12.3.2 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, 2016). 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 in 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).

The technologies assessed by the abovementioned surveys and the distribution of fuel combustion by technologies are reported in Table 3.32.

Table 3.32 *Distribution of wood combustion by technologies*

Distribution of wood combustion by technologies						
	1999	2006	2012	2015	2018	2019
				%		
Fireplaces	51.3	44.7	51.2	49.0	41.0	40.3
Stoves	28.4	27.6	22.9	21.0	19.0	18.4
Advanced fireplaces	15.4	20.2	15.8	15.0	20.0	19.7

Distribution of wood combustion by technologies						
	1999	**2006**	**2012**	**2015**	**2018**	**2019**
Pellet stoves	0	3.1	4.0	9.0	12.0	13.6
Advanced stoves	4.8	4.4	6.0	6.0	8.0	7.9

Average emission factors for 1999, 2006, 2012, 2015, 2018 and 2019 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 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' (SSC, 2012) 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 results 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 exception of emissions from pellet stoves which are higher of 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. 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. The complete results of this study will be used for the next submission.

In Table 3.33 emission factors used for the Italian inventory are reported.

Table 3.33 *Emission factors for wood combustion*

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2018**	**2019**
				g/Gj				
NO_x	50	55	59	61	61	61	61	66
CO	6000	5791	5591	5427	5395	5010	5010	4633
NMVOC	762	715	672	643	638	597	597	535
SO_2	10	11	12	13	13	13	13	14
NH_3	9	7	6	6	6	6	6	5
PM10	507	465	428	409	406	392	392	352
PM2.5	503	461	424	405	402	388	388	348
BC	40	37	35	34	34	33	33	31
PAH	0.25	0.24	0.23	0.23	0.22	0.21	0.21	0.19
Dioxin (µg/GJ)	0.48	0.47	0.45	0.44	0.43	0.40	0.40	0.37
PCB	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
As	0.001	0.001	0.001	0.001	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

	1990	1995	2000	2005	2010	2015	2018	2019
				g/Gj				
Cr	0.001	0.002	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
Hg	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
Pb	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03
Se	0.001	0.001	0.001	0.001	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
B(a)P	0.07	0.07	0.07	0.07	0.07	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
B(k)F	0.04	0.04	0.04	0.04	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

In 2014 the national Institute of Statistics (ISTAT) carried out a survey, funded by the Ministry of Economic Development and infrastructure (MSE), 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, MSE 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 in 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 have been completely recalculated affecting the relevant pollutants and resulting in important recalculations at national total levels.

3.12.4 Time series and key categories

The time series of emissions for civil sector shows an increasing trend for all 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. All the 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 of 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 2019 by fuels are shown in the following box.

EMISSION FACTORS (kg/Gj)		
FUEL	**1990**	**2019**
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
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	-	-

EMISSION FACTORS (kg/Gj)		
FUEL	**1990**	**2019**
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 3.34.

Table 3.34 *Time series of emissions in civil sector: small combustion and off-road vehicles*

		1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
SO_X (Gg)	1A4	96.47	42.66	26.39	22.86	12.13	10.30	10.31	10.14	10.42	10.21
	1A5	1.19	0.81	0.21	0.17	0.13	0.12	0.15	0.08	0.10	0.13
NO_X (Gg)	1A4	174.96	187.20	171.81	163.05	144.04	127.00	126.54	125.00	123.90	121.66
	1A5	11.16	11.99	7.24	13.50	6.11	3.29	3.28	2.36	2.05	2.73
CO (Gg)	1A4	1093.21	1088.79	1028.01	997.44	1716.14	1440.68	1392.67	1515.61	1331.31	1310.30
	1A5	65.12	79.02	45.49	54.48	17.33	16.49	19.73	11.93	13.23	17.42
PM10 (Gg)	1A4	84.63	89.76	84.57	80.33	129.12	110.17	106.56	115.77	97.69	96.20
	1A5	1.27	1.54	0.90	1.60	0.81	0.47	0.49	0.34	0.31	0.42
PM2.5 (Gg)	1A4	83.81	89.07	83.93	79.64	127.78	108.97	105.40	114.50	96.50	95.03
	1A5	1.27	1.54	0.90	1.60	0.81	0.47	0.49	0.34	0.31	0.42
BC (Gg)	1A4	14.90	16.14	14.64	12.41	13.74	10.99	10.57	11.17	9.86	9.60
	1A5	0.72	0.82	0.49	0.92	0.46	0.25	0.25	0.18	0.16	0.21
Pb (Mg)	1A4	81.95	34.29	24.64	46.34	16.46	15.11	14.56	15.24	14.44	14.15
	1A5	16.34	4.22	1.16	0.00	NA	0.12	0.02	0.02	0.09	0.18
Cd (Mg)	1A4	1.51	1.21	1.74	2.62	0.66	0.55	0.53	0.55	0.51	0.49
	1A5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hg (Mg)	1A4	0.61	0.71	1.04	1.97	0.52	0.49	0.48	0.49	0.49	0.48
	1A5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PAH (Mg)	1A4	32.06	35.44	35.91	39.08	67.42	56.10	54.33	59.39	52.33	51.41
	1A5	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00
HCB (Kg)	1A4	2.55	3.64	6.98	7.14	5.11	3.80	3.91	4.09	4.55	4.66
	1A5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCB (Kg)	1A4	14.92	18.33	25.73	36.26	22.01	18.99	18.70	20.20	19.55	19.71
	1A5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

3.12.5 **QA/QC and Uncertainty**

Basic data used in the estimation process are reported by Ministry of Economic Development in the National Energy Balance (MSE, 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.

3.12.6 **Recalculation**

Some recalculations affected 1A4 category in this submission.

Energy recovery from waste reported in the commercial heating has been updated from 2016 because of the update of activity data.

PM emission factor from natural gas and LPG combustion in 1.A.4.b.i. has been updated on the basis of the experimental evidence (Innovhub, 2016).

According to the review process, the update of different EFs occurred producing recalculations for NMVOC, NO_X and PM. EFs for NOX from 1A4ai and EFs for NOX, NMVOC and PM from 1A4bi have been updated since 2000 on the basis of the 2019 EMEP/EEA Guidebook.

3.12.7 **Planned improvements**

The updating of average emission factors is planned for future submission 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 a 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, 2019) will be carried out and emission factors will be updated as needed.

3.13 FUGITIVE EMISSIONS (NFR SUBSECTOR 1.B)

3.13.1 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.

In Table 3.35 the list of categories for fugitive emissions identified as key categories by pollutant for 2019, 1990 and in the trend is reported.

Table 3.35 *List of key categories by pollutant in the civil sector in 2019, 1990 and trend*

	Key categories in 2019	*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
NMVOC	1 B 2 b	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	1 B 2 d

3.13.2 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 (MSE, 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 (MSE, several years [a]) and emission factor 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 (MSE, 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 NH3 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. According to the review (EEA, 2019; EEA, 2020), PAH emissions from coke production has been also estimated with emission factor from the 2019 EMEP/EEA Guidebook (EMEP/EEA, 2019) and allocated in 1.B.1b.

Oil exploration and production (1B2a i)

NMVOC emissions have been calculated according with activity data published on national energy balance (MSE, several years [a]), data by oil industry association (UP, 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 (MSE, several years [a]) and occur prevalently from processes in refineries.

This category is key for SO_X in 2018, 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 (MSE, several years [a]) or supplied by oil industry association (UP, 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 Petrolifera, 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. We plan to address this issue for the next submission according to the Tier 2 EFs provided in the 2019 EMEP/EEA Guidebook.

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 with 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 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).

Flaring in refineries (1B2c)

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 has 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 2019, the base year and the trend while NH_3 is key 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 (MSE, several years [a]) while emission data resulting by the monitoring are issued by ARPAT and reported from 2000 on yearly basis (ARPAT, several years). For earlier years emission factors of 2000 have been used.

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

NMVOC emissions from this category is key category for 2019 and trend. 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 3.36. The methodology and references are reported in detail in the NIR (ISPRA, 2021[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 (AEEG); 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 3.36 *Average composition for pipelines natural gas and main parameters*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
HCV (kcal/m$_3$)	9,156	9,193	9,215	9,261	9,325	9,303	9,351	9,340	9,334	9,335
NCV (kcal/m$_3$)	8,255	8,290	8,320	8,354	8,412	8,391	8,444	8,433	8,427	8,428
Molecular weight	17.03	17.19	17.37	17.45	17.46	17.34	17.53	17.44	17.34	17.29
Density (kg/Sm$_3$)	0.72	0.73	0.74	0.74	0.74	0.73	0.74	0.74	0.73	0.73
CH_4 (molar %)	94.30	93.36	92.22	91.93	92.04	92.72	91.54	92.08	92.64	92.92
NMVOC (molar %)	3.45	4.09	4.84	5.35	5.74	5.26	6.17	5.93	5.62	5.49
CO_2 (molar %)	0.22	0.20	0.18	0.49	0.75	0.70	0.65	0.67	0.74	0.64
Other no carbon gas (molar %)	2.03	2.34	2.76	2.24	1.48	1.32	1.64	1.33	1.00	0.95
CH_4 (weight %)	88.83	87.14	85.16	84.53	84.54	85.81	83.79	84.72	85.68	86.23
NMVOC (weight %)	7.33	8.62	10.00	10.73	11.27	10.34	12.03	11.51	10.87	10.64
CO_2 (weight %)	0.57	0.51	0.47	1.23	1.89	1.78	1.62	1.70	1.88	1.63
Other no carbon gas (weight %)	3.27	3.74	4.37	3.51	2.30	2.08	2.55	2.07	1.56	1.50

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 include also 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 3.37 provides the trend of natural gas distribution network length for each pipeline material and the average CH_4 emission factor.

Table 3.37 *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	2017	2018	2019
Steel and cast iron (km)	102,061	131,271	141,848	154,886	198,706	203,116	204,890	205,273	206,855
Grey cast iron (km)	24,164	22,784	21,314	15,080	4,658	2,398	2,088	2,063	2,061
Polyethylene (km)	775	8,150	12,550	31,530	49,663	56,943	59,368	59,358	59,593
Total (km)	**127,000**	**162,205**	**175,712**	**201,496**	**253,027**	**262,457**	**266,346**	**266,693**	**268,509**
CH_4 EF (kg/km)	1,958	1,417	1,228	1,000	719	551	537	488	458
NMVOC EF (kg/km)	162	140	144	127	96	66	73	62	56

3.13.3 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.

3.13.4 QA/QC and Uncertainty

Different data sources are used for fugitive emissions estimates: official statistics by Economic Development Ministry (MSE, several years [a], [b]), by Transport of Infrastructure Ministry (MIT, several years); national authorities (AEEG, several years; ISTAT, several years [a]), gas operators (ENI, several years; 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).

3.13.5 Recalculation

No recalculations occurred.

3.13.6 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 2019, industrial processes account for 11.9% of SO_2 emissions, 0.8% of NO_X, 0.2% of NH_3, 4.77% of NMVOC and 3.6% of CO. About particulate matter, in 2019 this sector accounts for 7.06% of PM10 emissions and 5.96% 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 37.4% of Pb emissions, 32.9% of Cd and 44.0% of Hg. Regarding POPs emissions, 13.8% of PAH total emissions is emitted from industrial processes as well as 31.3% of dioxins and 74.7% of PCB.

In 2019, *iron and steel* sector (2C1) is a key category at level assessment for PM10, PM2.5, Pb, Cd, Hg, PAH, PCDD/F and PCB; emissions from *cement production* (2A1) is a key category source for SO_2 emissions as well as other chemical industry (2B10a). Emissions from *cement production* (2A1) is a key category source for PM10 too. Emissions from *fireworks* (2G) is a key category for Cd. 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, *fireworks* (2G) is a key category for Cd and *iron and steel production* (2C1) is a key category for PM10, PM2.5, Cd, Hg, PAH, PCDD/F and PCB. At trend assessment, *iron and steel* sector is key category for Pb, Cd, Hg, PAH, PCDD/F and PCB while *cement production* is a key category for SO_2 emissions, other chemical industry (2B10a) is a key category for Hg and *fireworks* (2G) is a key category for Cd emissions.

4.2 METHODOLOGICAL ISSUES

Methodologies used for estimating emissions from this sector are based on and comply with the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007) and EMEP/EEA guidebook (EMEP/EEA, 2019), the IPCC Guidelines (IPCC, 1997; IPCC, 2006) and the Good Practice Guidance (IPCC, 2000). Included also in this sector are by-products or fugitive emissions, which originate from industrial processes.

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, references derive from data collected in the framework of the national PRTR reporting obligation, the Large Combustion Plant directives and the European Emissions Trading Scheme. Other small plants communicate their emissions which are also considered individually. These processes have improved the 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 and lime production.

Cement production (2A1), is considerable for SO_2 and PM2.5 emissions and accounts for 5.5% and 1.41% of the respective total national emissions in 2019.

During the last 15 years, in Italy, changes in cement production sector have occurred, leading to a more stable structure confirming the leadership for the production in Europe. The oldest plants closed, wet processes were abandoned in favour of dry processes so as 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. At January 1st 2020, 18 companies (55 plants of which: 32 full cycle and 23 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: 42% is in northern Italy, 15% is in the central regions of the country and 44% is in the southern regions and in the islands (Federbeton/AITEC, 2020). In Italy different types of cement are produced; as for 2019 Federbeton/AITEC, the national cement association, has characterised the national production as follows: 71% is CEM II (Portland composite cement); 16% is CEM I (Portland ordinary cement); 12% is CEM IV (pozzolanic cement) and 1.6% is CEM III (blast furnace cement). Clinker production has been decreasing since 2007 but has kept basically the same since 2016; clinker demand in cement production was about 78% in 2019 (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 legislation.

In this category only SO_2 and PM emissions are reported separately from combustion while all the other pollutant emissions are included in the energy sector in 1.A.2f category.

Emission factor for PM10 emissions is equal to 130 g/Mg of cement for the whole time series and is calculated on the basis of plants emission data in the nineties.

Regarding SO_2 emissions, emission factors are derived from activity and emission data supplied directly by the cement facilities in the context of the national PRTR reporting obligation; these figures are available from 2002 and refer both to the combustion and process. In 2003, the total average emission factor derived from the communications by the production plants was equal to 650 g/t of cement produced; this value has been split into 350 g/t for the combustion and 300 g/t for the process in accord with the default EF reported in the 1996 IPCC guidelines. Both these values have been also used for previous years of the time series back to 1995. For the years from 1990 to 1994, the same EF has been used for the combustion process while for estimating emissions from the process an EF equal to 500 g/t, as suggested by the EMEP/CORINAIR Guidebook, has been used in consideration of the S content in the prevalent fuel used in the process (coal) at national scale. From 2004 onwards, the total SO_2 EF from cement production plants has been calculated on the basis of the data reported to the national EPER/E-PRTR register, setting the EF for process at 300 g/t and varying the combustion EF accordingly (EF Tot = EF Proc + EF comb).

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. On the basis of the 2017 review process (EEA, 2017 [a]), the previous notation key has been replaced by the IE notation key.

About the 2A5 category, following the suggestions of the NEC review more information has been added but different activities have to be dealt separately. As regards 2A5a *Quarrying and mining of minerals other than coal*, there is no evidence of active mines of the main minerals as those indicated in the Guidebook (bauxite, copper, manganese and zinc). All these mines closed before 1990 for economic reasons. At the same time there is no available data to apply a Tier 1 on other mineral mines. The USGS Mineral yearbook provides info for Italy only for Feldspar, Gypsum, Pumice and Sand and gravel extraction. All the data are estimated and we are verifying the activity level with industry and local competent authorities. Moreover, it should be verified if the EFs available in the Guidebook are applicable to these national extractive activities because of the abatement technologies and the kind of mineral. A first rough estimation of emissions has been done using the spreadsheet available in the 2019 EMEP/EEA Guidebook (2.A.5.a Quarrying and mining calculation model 2019 - Spreadsheet.xlsx), introducing production data for 2016 (last year available) as reported in the USGS database for crushed rocks, sand and gravels without modifying the other default values introduced (e.g. the number of plants) because at the moment these are unknown. Recycled aggregates have not been included in the calculation since crushed asphalt is recycled in specific plants and these emissions are already reported under the relevant category while for crushed concrete there are no specific information available in the USGS statistics and no other statistics are available that could be used instead. It should be noted that the concrete inert material in Italy go prevalently to landfills. PM2.5 emission estimates results in 1.3 kt where most part of emissions are due to the internal transportation (1.1 kt), mostly due to resuspension of particles which do not seem be included in the inventory (for road transport it is not). As for the category 2A5b *Construction and Demolition*, no statistical data are available (as annual surfaces) to allow an estimation. Only economic data are provided by the National Institute of Statistics and, as reported in the review report, "The TERT has not been able to assess whether this issue is below or above the threshold of significance for a technical correction, due to the lack of information on activity data provided by the 2016 EMEP/EEA Guidebook and the high variability among countries of the implied emission factors based on socioeconomic variables". Because of that further investigations are under way. According to the Guidebook to estimate emissions from this category there is need to have an idea of the surface involved in the work or at least of the number of activities of construction divided by typology on going in the country. A study is under finalisation estimating the land use change and relative loss of soils and we plan to start from that work to estimate a reliable time series of construction activities in the country with the aim to apply Tier 1 methodology. Alternatively, the evaluation of environmental permits for some construction work of national interest such as road or railway constructions could be used but the number of works is not representative of the national works. 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 Guidebook.

As already mentioned, *other chemical industry* (2B10a) was key category for Hg emissions in 1990 and for SO_x emissions in 2019. 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 2019 to 249,072 tonnes. Activity production data are supplied by the National Institute of Statistics (ISTAT) and published in the official national statistics and since 2002 data have also been collected at 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 for the last years is a consequence of both the conversion of production plants from the mercury cells process to the membrane technology and also 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 with mercury cells was obliged to stop the production with this process and it is still in operation although the manufacturing process has been relying on the purchase of the intermediate products since then.

Emissions from sulphuric acid production, also reported in *other chemical industry* (2B10a) account for 4.71% of total SO_X emissions in 2019. Activity production data are supplied by the National Institute of Statistics (ISTAT) and published in the official national statistics 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 CORINAIR inventory project and of the national EPER/E-PRTR, respectively.

On the basis of the 2017 review process NOx, SOx, CO, PM and BC emissions from 2B7 *Soda ash production* have been 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 under 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 achieved estimates, using the EMEP/EEA EFs, produced figures of around 20 Mg (PM10) consistently with respect to the E-PRTR thresholds.

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. In 2019, there are only two of the above mentioned plants, one of which lacks BOF; oxygen steel production represents about 18.2% of the total production and the arc furnace steel the remaining 81.8% (FEDERACCIAI, several years). Currently, long products represent about 46% of steel production in Italy, flat products about 42%, and pipe the remaining 12%. Most of the flat production derives from only one integrated iron and steel plant 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).

Basic information for *Iron and steel production* derives from different sources in the period 1990-2019. 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 2019, *iron and steel sector* (2C1) is key category for PM10, 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 2019*

		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		60	37.5						
Pig iron tapping		41.4	25.9	0.3	0.3	15		950	
Basic oxygen furnace	*Areal*	62	54.3	25	3	850	3.6		
	Point	122	106.8	25	3	850	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	6.0	4.8						

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.

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 2019 the average emission factor is equal to 0.38 micrograms TEQ per Mg of sinter produced. EF is calculated yearly on the basis of measurements done in the two 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" no distinguish between combustion and process) EF=0,032mg/Mg in 1A2a because in this case HCB emissions are clearly linked to the combustion activities. The 2016 Guidebook is referred to the 2006 version.

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 (EMEP/EEA, 2019). 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. As discussed during the recent review process (EEA, 2018), indeed, no plants for aluminium production by electrolysis work in Italy from 2012 and pollutants time series are reported, obviously, from 1990 to 2012. PCDD/Fs emissions occur almost exclusively from secondary aluminium production and are consequently linked to the combustion process and reported in 1A2b. More, 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.

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 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, 2021). 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 EMEP/EEA Guidebook 2019 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 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 NMVOC emissions from *food and drink* (2H2) accounting for 2.7% of the national total in 2019 and Cd from fireworks which is key category a. Emissions from this category 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) 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. PRODCOM data collection has improved along the years producing more reliable figures. 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 relative 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).

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 was no 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 2016 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".

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 for tobacco data on consumption were collected from the Ministry of Health, observatory of tobacco smoking. Emission factors are those reported in the EMEP/EEA 2019 Guidebook (EMEP/EEA, 2019).

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 statistics for that kind of wood production and emission factor in the EMEP/EEA 2019 Guidebook 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 2019*

	2A1	2A2	2B1	2B2	2B3	2B6	2B7	2B10a	2C1	2C2	2G	2H1	2H2	2L
								%						
SO_x	5,50		0,01			0,23	0,14	4,71	1,26		0,01			
NO_x			0,03	0,04	0,00	0,01	0,02	0,32	0,39		0,02			
NH_3			0,00	0,00			0,11	0,02			0,08			
NMVOC			0,01					0,21	0,35		1,28	0,18	2,73	
CO			0,00				0,46	0,74	2,17		0,20			
PM10	2,06	0,69				0,00	0,01	0,22	2,80		1,26		0,01	
PM2.5	1,41	0,17				0,00	0,01	0,11	2,84		1,41			
BC	0,33	0,01				0,00	0,00	0,01	0,11					
Pb									34,74		1,69			0,98
Cd								0,93	23,95		8,06			

	2A1	2A2	2B1	2B2	2B3	2B6	2B7	2B10a	2C1	2C2	2G	2H1	2H2	2L
								%						
Hg									44,09					
PAH									13,78		0,01			
Dioxin									31,22		0,00			
HCB														
PCB									74,74					

Note: key categories are shaded in blue

There is a general reduction of emissions in the period 1990 - 2019 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.

4.3.1 **Mineral products (2A)**

As mentioned above, PM10 emission factor for cement production is set constant from 1990 to 2019 while SO_2 emission factor reduced from 1990 to 1995 and is set constant in the subsequent years. Consequently, the trends of SO_2 and PM10 emissions follow that of the activity data.

In Table 4.3, activity data, SO_2 and PM10 emissions from cement production are reported.

Table 4.3 *Activity data, SO_2 and PM10 emissions from cement production, 1990 – 2019 (Gg)*

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Activity data [Gg]	42,414	35,432	41,119	47,291	34,283	32,800	26,244	23,083	21,542	20,825
SO_2 emissions (Gg)	21.21	10.63	12.34	14.19	10.28	9.84	7.87	6.92	6.46	6.25
PM10 emissions [Gg]	6.7	6.73	6.98	7.75	5.91	5.3	4.49	3.95	3.71	3.63

4.3.2 **Chemical industry (2B)**

Other chemical industry (2B10a) was a key category for Hg emissions in 1990 and for SO_x in 2019 and for Hg at trend assessment. Hg emissions refer to chlorine production with mercury cells process; in Table 4.4, 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 in Hg emissions for the last years 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 4.4 *Activity data and Hg emissions from chlorine production, 1990 – 2019*

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Activity data [Gg]	1,043	869	786	535	258	218	116	237	281	249

Hg emissions [Mg]	3	2	1	0.48	0.12	0.04	0.01	0.03	-	-

SO_X emissions are prevalently 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 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 19.0 Mt in 2019.

In Table 4.5, 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 2019 average emission factor is equal to 0.38 micrograms TEQ per Mg of sinter produced. EF is calculated yearly on the basis of measurements done in the two existing sinter plant in Italy.

Table 4.5 *Activity data and HMs, PCB and PCDD/PCDF emissions from electric arc furnace, 1990 – 2019*

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Steel production **EAF** [kt]	15,102	16,107	15,879	17,661	17,115	17,255	17,704	19,336	19,983	18,980
Cd emissions **EAF** [Mg]	1.1	1.1	0.8	0.9	0.9	0.9	0.9	1.0	1.0	0.9
Cd emissions **2C1** [Mg]	1.3	1.4	1.1	1.2	1.1	1.0	1.0	1.1	1.1	1.1
Hg emissions **EAF** [Mg]	2.3	2.4	2.4	2.6	2.6	2.6	2.7	2.9	3.0	2.8
Hg emissions **2C1** [Mg]	2.3	2.5	2.4	2.7	2.6	2.6	2.7	2.9	3.0	2.9
Pb emissions **EAF** [Mg]	52.1	55.6	54.8	60.9	59.0	59.5	61.1	66.7	68.9	65.5
Pb emissions **2C1** [Mg]	61.1	65.7	64.1	71.0	66.5	63.7	66.0	70.8	72.9	69.1
PCB emissions **EAF** [kg]	54.4	58.0	57.2	63.6	61.6	62.1	63.7	69.6	71.9	68.3
PCB emissions **2C1** [kg]	91.7	100.0	95.8	105.7	92.7	79.3	84.1	86.6	88.2	88.5
PCDD/F emissions **EAF** [g T-eq]	67.2	71.7	70.7	78.6	76.2	76.8	78.8	86.0	88.9	84.5
PCDD/F emissions **2C1** [g T-eq]	67.2	71.7	70.7	78.6	76.2	76.8	78.8	86.0	88.9	84.5

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 2019 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 year 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 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, NOx 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.

Following the decision 2012/17 of the Executive Body of the Convention on Long Range Transboundary Air Pollution, that requests Italy to submit information concerning the status and details of its work to improve the emission inventory of PAH, Italy in recent years has reviewed the estimates regarding PAH major sources. In the 2013 submission different recalculations have been performed in the energy and waste sector, emissions from iron and steel production have been revised in the 2014 submission. The most important update regards pig iron tapping emission factor that considers, from 2000 onwards, the abatement due to fabric filters and the relevant EF derived from the Guidebook EMEP/CORINAIR 2006 (0.95 g/Mg). Investigations on the largest integrated plant in Italy confirmed the installation of fabric filters on each point of emission related to pig iron tapping (MATTM, 2011). 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 4.6, activity data and PAH emissions from integrated plants and from the whole sector 2C1 are reported.

Table 4.6 *Steel production data and PAH emissions from integrated plants, 1990 – 2019*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Pig iron production [Gg]	11,852	11,678	11,209	11,424	8,555	5,051	6,054	5,071	4,845	4,619
Steel production BOF [Gg]	10,365	11,664	10,744	11,688	8,635	4,763	5,669	4,732	4,520	4,211
PAH emissions i.p.* [Mg]	41.9	41.3	11.7	12.1	9.2	5.8	6.8	5.9	5.7	5.4
PAH emissions 2C1 [Mg]	44.9	44.5	14.3	15.1	11.9	8.2	9.4	8.6	8.4	8.0

*i.p.: integrated plants

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

Emissions from these categories are usually negligible except for Cd emissions from use of *fireworks* accounting for 8.1% in 2019 of cadmium national totals and for NMVOC emissions from *food and drink* (2H2) accounting for 2.7% 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 4.7, activity data and NMVOC emissions from sector 2H2 are reported.

Table 4.7 *Activity data and NMVOC emissions from sector 2H2***,** *1990 – 2019*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Activity data - Bread [Gg]	4,153	3,882	3,565	4,109	4,161	3,877	3,670	3,749	3,311	3,796

Activity data – Wine [10^6 dm^3]	5,521	5,620	5,409	5,057	4,673	5,073	5,414	4,610	5,660	5,219
Activity data – Beer [10^6 dm^3]	1,215	1,199	1,258	1,280	1,281	1,429	1,452	1,567	1,642	1,725
Activity data – Spirits [10^6 dm^3]	268	232	206	161	115	98	100	101	100	108
NMVOC emissions [Gg]	31.7	29.2	26.8	27.5	25.9	24.3	23.6	23.6	22.0	24.5

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 are disaggregated at regional and provincial level and figures are compared with results obtained by regional bottom up inventories. 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 2015 is reported in Figure 4.1; methodologies are described in the relevant publication (ISPRA, 2009).

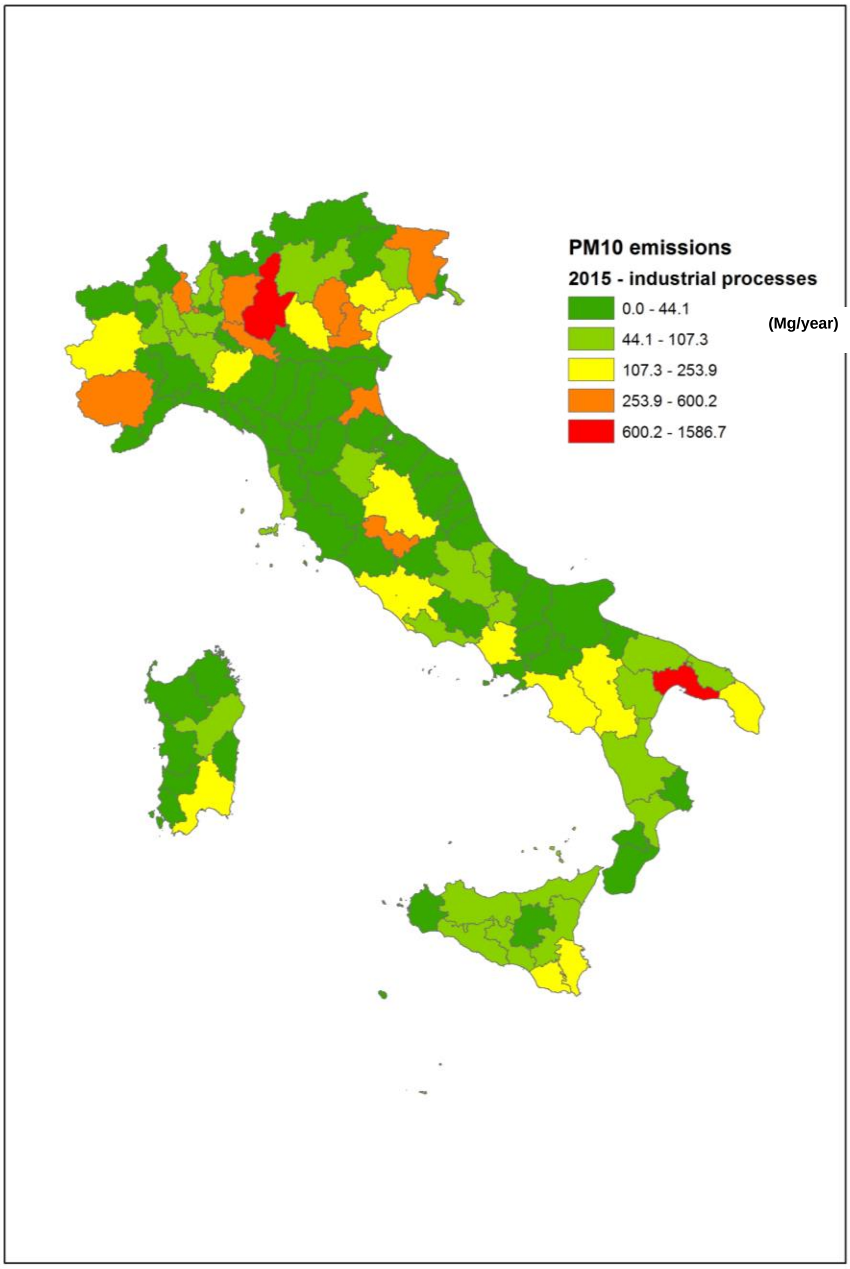


Figure 4.1 *PM10 emissions from industrial processes in 2015 (t)*

4.5 RECALCULATIONS

4.5.1 Mineral industry (2A)

Recalculations occur because of the update of PM10 emission estimates for cement process (1990-2018) following the recommendation of the review process (EEA, 2020), due to the fact that emission factor in the Guidebook is related to clinker production instead of cement production. Minor recalculations occurred because of the update of activity data for glass production (2017 and 2018).

4.5.2 Chemical industry (2B)

Recalculations occur because of the update of NMVOC emission factor for organic chemical industry due to the update of the activity data for 2017 and 2018.

4.5.3 Metal industry (2C)

Minor recalculations occur in 2017-2018 because of the update of activity data regarding steel products.

4.5.4 Other product use (fireworks and tobacco) (2G)

Recalculations have been implemented for the update of activity data in the consumption of tobacco from 2004 and the consideration of activity data on the use of fireworks instead of explosives, following the results of the ESD review (EEA, 2020).

4.5.5 Other industrial processes (2H)

Recalculations occur in this category in 2018 for NMVOC emissions because of the update of activity data for the following source categories: chipboard, bread, beer, and spirits.

4.6 PLANNED IMPROVEMENTS

Following the suggestions of the last review in the framework of NEC Directive (EEA, 2020), further investigations are under way for the categories 2A5a and 2A5b regarding reliable activity data.

Activities 2C3, 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 the 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 wool enduction, printing industry, fat, edible and non-edible oil extraction, preservation of wood, application of glues and adhesives, vehicles dewaxing.

According to the review process we are still exploring if Hg emissions from fluorescent tubes occur in Italy. No other emissions from the sector occur.

NMVOC emissions from 2D3a, 2D3d, 2D3g, 2D3h and 2D3i are key categories in 2019; the same categories, except 2D3h plus 2D3e, were also key categories in 1990. For the trend 1990-2019, 2D3a, 2D3d and 2D3g result as key categories.

The sector accounts, in 2019, for 41% of total national NMVOC emissions, whereas in 1990 the weight out of the total was equal to 31.08%. Total sectoral NMVOC emissions decreased by 40.8%, between 1990 and 2019.

PM10 emissions account for 1.35%, while PM2.5, BC and PAH emissions are also estimated but they account for less than 1%.

In Figure 5.1 the share of NMVOC emissions of the sector is reported for the years 1990 and 2019.

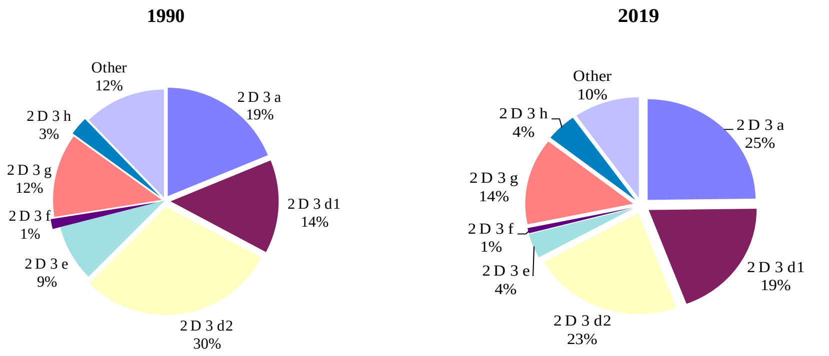


Figure 5.1 *Share of NMVOC emissions for the solvent use sector in 1990 and 2019*

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 (Vetrella, 1994; EMEP/CORINAIR, 2007; EMEP/EEA, 2016). 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; FIAT, several years), solvent use in dry cleaning (ENEA/USLRMA, 1995), solvent use in textile finishing and in the tanning industries (Techne, 1998; Regione Toscana, 2001; Regione Campania, 2005; GIADA, 2006). 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 considered period.

A more detailed description is reported for the 2019 key categories of NMVOC emissions in the following sections.

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) supplied by the National Institute of Statistics (ISTAT, several years [a] and [b]) 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.

Emission factors

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. For leather, shoes, wood etc. and car maintenance products, figures are taken from BiPro Association. For insecticides and disinfectants, emission factors derive from national studies at local level.

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 **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 [a] and [b]).

From 2007 onwards, data are also provided by SSOG (Stazione Sperimentale per le industrie degli Oli e dei Grassi, *Experimental Station for Oils and Fats Industries*), 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 qualitative 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. 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 wood are one of the biggest contributors 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.

5.2.3 **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 [a] and [b]). The default emission factor (provided by the EMEP 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 [a] and [b]). 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).

5.2.4 Degreasing (2D3e)

NMVOC emissions have been estimated for this category. The emission factor used (1000 g NMVOC/Mg solvent) and refers to the percentage of NMVOC emitted per tones of solvent used and it is not directly comparable to those provided in the Guidebook (700g/kg cleaning product). 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 whereas it has been assumed that the percentage of NMVOC emissions remains constant. The EF used in the inventory comes from the "Corinair 1992 Default Emission Factors Handbook" but taking in consideration the comments from the last reviews it has not been assumed that around 10% of the solvent remains in the product or is destroyed; so the EF has been changed from 900 to 1000 g NMVOC/Mg solvent. Activity data, solvent used, are also provided by the relevant industrial association (Federchimica, several years). According to the review process we are verifying how to apply the emission factors available in the EMEP/EEA Guidebook that refers to the volumes of cleaning products used instead of the solvent used but the information on the amount of cleaning products in the sector is not yet available.

5.2.5 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 in 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 Guidebook EMEP, 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.

5.2.6 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 [a] and [b]), whereas emission factors are from the EMEP/CORINAIR 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 plant 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 plant have 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/CORINAIR guidebook considering national information on the solvent content in products supplied by the specific industrial associations.

As regard rubber processing, emission factors for the first years of nineties have been provided by the industrial association. The use of the Swedish emission factor from 1997 was justified in lack of other updated data.

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, emission factor for 1990 is from Legislative Decree 152/2006, equal to the maximum VOC content limit value (150 g/m2). 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.

As regards asphalt blowing and possible PAH and Benzo(a)pyrene emissions as suggested by the 2016 EMEP/EEA Guidebook, 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.

5.2.7 **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 [a] and [b]) 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) whereas default emission factors do not change over the period.

5.3 TIME SERIES AND KEY CATEGORIES

The sector accounts, in 2019, for about 41% of total national NMVOC emissions. PM, BC and PAH emissions are also estimated in this sector but they account for less than 1%.

NMVOC emissions from the use of solvent decreased from 1990 to 2019 of about 40.8%, from 619 Gg in 1990 to 367 Gg in 2019, mainly due to the reduction of emissions in paint application, in degreasing and dry cleaning and in other product use. 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 in 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 2019 with respect to 1990 by sub-sector.

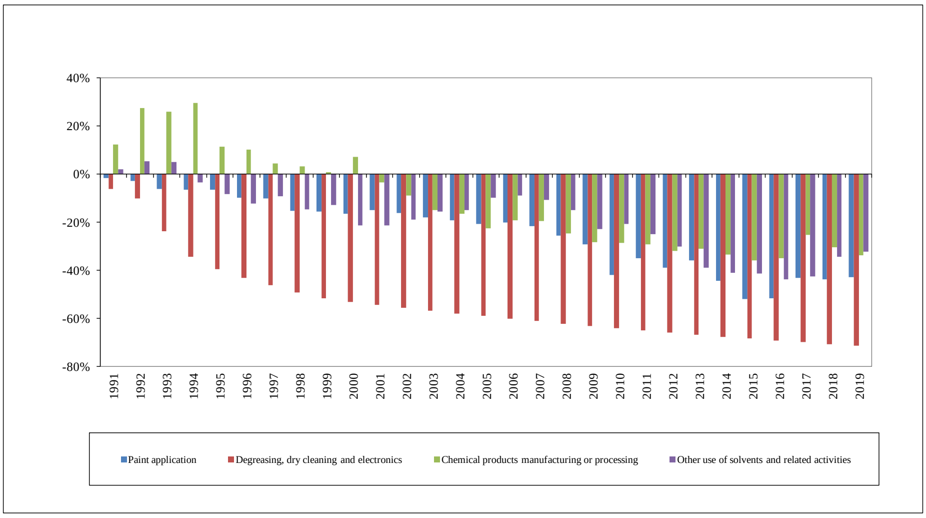


Figure 5.2 *Trend of NMVOC emissions from 1991 to 2019 as compared to 1990*

The main source of emissions is *paint application* (2D3d) where NMVOC emissions derive mainly from wood application and construction and building. The second source of emissions is *domestic solvent use* (2D3a), mostly for the consumption of cosmetics, followed by *chemical products and other product use* (2D3g), especially for emissions deriving from polyurethane processing, paints manufacturing and leather tanning.

Table 5.1 represents the pollutants estimated in the sector and the key categories identified.

Table 5.1 *Key categories in the IPPU - Solvent and other product use sector in 2019*

	2D3a	2D3b	2D3c	2D3d	2D3e	2D3f	2D3g	2D3h	2D3i
SO_x									
NO_x									
NH_3									
NMVOC	10.17	0.92	0.00	17.26	1.62	0.35	5.71	1.88	3.09
CO									
PM10		1.32	0.03				0.01		
PM2.5		0.22	0.01				0.01		
BC		0.10	0.00						
Pb									
Cd									
Hg									
PAH									0.02
Dioxin									
HCB									
PCB									

Note: key categories are shaded in blue

In Table 5.2 and 5.3 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.

			1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
06 01	**Paint application**											
06 01 01	Paint application : manufacture of automobiles	*vehicles*	2,865,857	2,521,355	2,770,104	1,766,930	1,310,425	1,326,711	1,433,047	1,499,956	1,443,870	1,293,241
06 01 02	Paint application : car repairing	*Mg paint*	22,250	17,850	24,276	23,475	19,479	25,395	32,521	35,217	38,728	37,416
06 01 03	Paint application : construction and buildings (except item 06.01.07)	*Mg paint*	111,644	120,736	125,928	163,455	168,358	158,661	159,823	157,265	161,199	196,105
06 01 04	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
06 01 05	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
06 01 06	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
06 01 07	Paint application : wood	*Mg paint*	150,000	150,000	140,000	140,000	123,250	80,000	75,000	80,000	75,000	75,000
	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
06 02	**Degreasing, dry cleaning and electronics**											
06 02 01	Metal degreasing	*Mg solvents*	52,758	32,775	25,895	22,237	19,095	16,398	15,906	15,429	14,966	14,517
06 02 02	Dry cleaning	*machines*	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
06 03	**Chemical products manufacturing or processing**											
06 03 01	Polyester processing	*Mg product*	179,852	197,882	168,704	112,188	89,638	94,389	96,522	109,510	109,510	109,510
06 03 02	Polyvinylchloride processing	*Mg product*	617,600	575,600	405,285	348,497	0	0	0	0	0	0
06 03 03	Polyurethane processing	*Mg product*	145,700	230,633	350,187	175,278	196,585	196,585	196,585	196,585	196,585	196,585
06 03 04	Polystyrene foam processing (c)	*Mg product*	85,004	80,400	90,200	35,200	33,692	46,800	36,200	51,200	44,100	51,600
06 03 05	Rubber processing	*Mg product*	671,706	700,859	810,124	831,187	607,667	545,989	557,079	613,364	631,709	603,318
06 03 06	Pharmaceutical products manufacturing	*Mg product*	80,068	88,094	104,468	106,861	110,183	120,907	126,068	131,052	137,321	136,202
06 03 07	Paints manufacturing	*Mg product*	697,129	747,417	900,683	964,631	891,882	851,450	770,497	940,682	905,943	885,576
06 03 08	Inks manufacturing	*Mg product*	87,527	110,667	132,256	132,521	133,979	108,600	102,949	92,708	115,533	112,953

			1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
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	3,080	3,023	2,870	2,614
06 01 02	Paint application : car repairing	*g/Mg paint*	700,000	700,000	605,500	605,500	497,810	617,377	587,616	567,101	551,450	527,187
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	149,364	222,552	220,326	209,310
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	54,360	75,720	73,050	72,516
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
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
06 01 07	Paint application : wood	*g/Mg paint*	446,500	425,000	406,300	390,750	377,250	354,000	342,500	340,000	339,500	333,250
	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
06 02	**Degreasing, dry cleaning and electronics**											
06 02 01	Metal degreasing	*g/Mg solvents*	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
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
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
06 03 02	Polyvinylchloride processing	*g/Mg product*	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
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
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
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
06 03 07	Paints manufacturing	*g/Mg product*	15,000	15,000	15,000	13,110	10,863	9,524	11,134	10,175	10,748	10,769
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
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

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 [a], [b] and [c]), 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 the framework of the MeditAIRaneo project, ISPRA commissioned to Techne Consulting S.r.l. a survey to collect national information on emission factors in the solvent sector. The results, published in the report "*Rassegna dei fattori di emissione nazionali ed internazionali relativamente al settore solventi*" (TECHNE, 2004), have been used to verify and validate emission estimates. In 2008, ISPRA commissioned to Techne Consulting S.r.l. another survey to compare emission factors with the last update figures published in the EMEP/CORINAIR guidebook (EMEP/CORINAIR, 2007). The results are reported in "*Fattori di emissione per l'utilizzo di solventi*" (TECHNE, 2008) and have been used to update emission factors for polyurethane and polystyrene foam processing activities.

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.

Verifications of the emissions from the sector occurred in 2012, on account of the bilateral independent review between Italy and Spain and the revision of national estimates and projections in the context of the National emission ceilings Directive for the EU Member States and the Gothenburg Protocol of the Convention on Long-Range Transboundary Air Pollution (CLRTAP). The analysis by category did not highlight the need of major methodological revisions of the sector; an additional source of emissions was added affecting only NMVOC emissions.

Furthermore, every five years 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 2015 is reported in Figure 5.3; methodologies are described in the relevant publication (ISPRA, 2009).

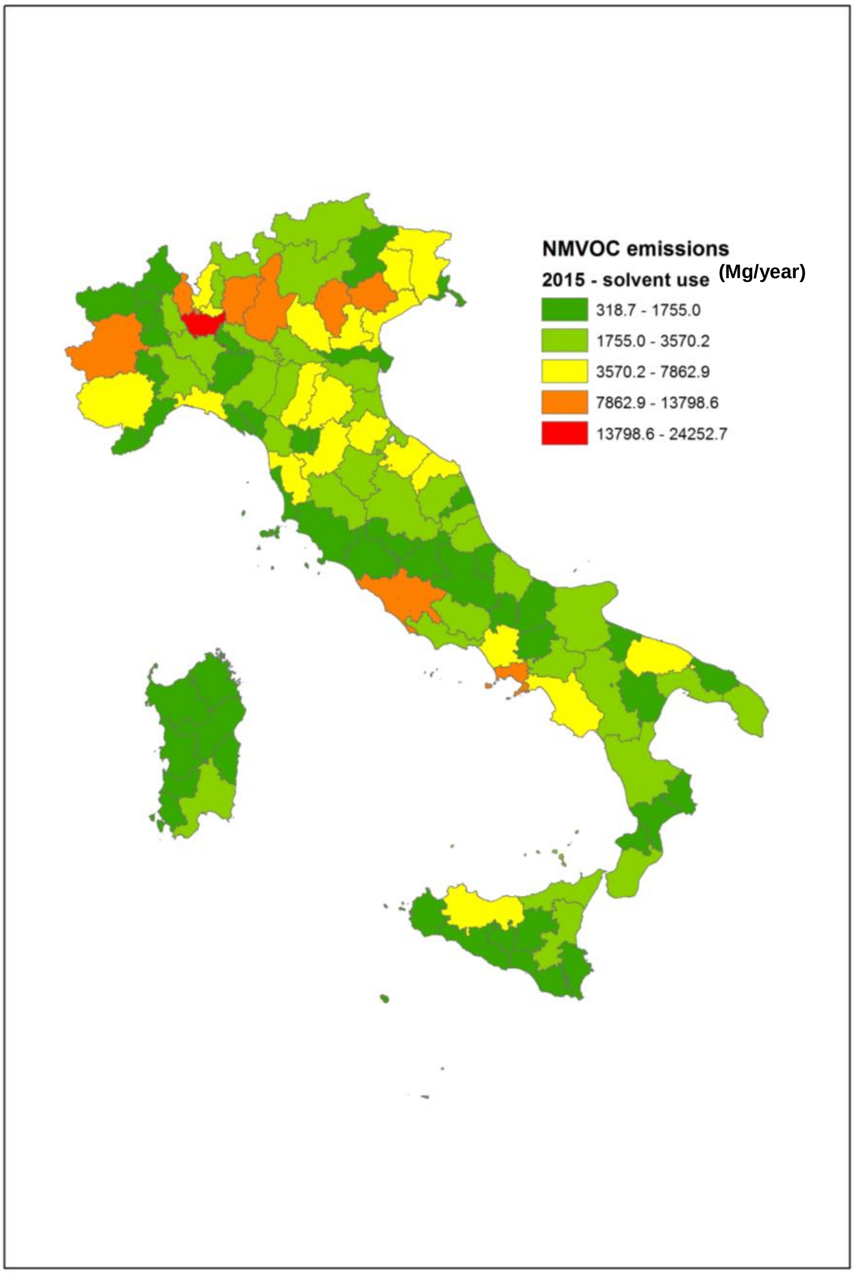


Figure 5.3 *NMVOC emissions from solvent and other product use in 2015 (t)*

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5.5 RECALCULATIONS

Minor recalculations occurred because of the update of activity data in the manufacture of automobiles, fat edible, aerosol cans and cosmetics in domestic solvent use.

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 to update the status of technologies in this sector where main challenges regard the availability of data collected from the industry. Main focus will be on metal degreasing and leather production where the EFs used need to be updated.

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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, NO_X, 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 2019, key categories level was identified for NH_3 emissions (3B1a, 3B1b, 3B3, 3B4gii, 3Da1 and 3Da2a), for NMVOC emissions (3B1a and 3B1b), for NO_X emissions (3Da1), for PM10 emissions (3Dc) and for HCB emissions (3Df). In 1990 similar figures were obtained except for NH_3 emissions 3B4gii and NO_X emissions which were not key categories and PM10 emissions 3B4gii which were key categories. For the trend analysis, key categories were related to NH_3 emissions (3B1a, 3B3, 3B4a, 3B4gi, 3B4gii, 3Da2a and 3Da2c), NO_X emissions (3Da2a), NMVOC emissions (3B1a and 3B1b), PM10 emissions (3Dc) and HCB (3Df).

In 2019, NH_3 emissions from the agriculture sector were 334.6 Gg (94.3% of national emissions) where 3B, 3D and 3F categories represent 56.4%, 37.7% and 0.2% of total national emissions. The trend of NH_3 from 1990 to 2019 shows a 25.5% 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 2019 is shown in Figure 6.1.

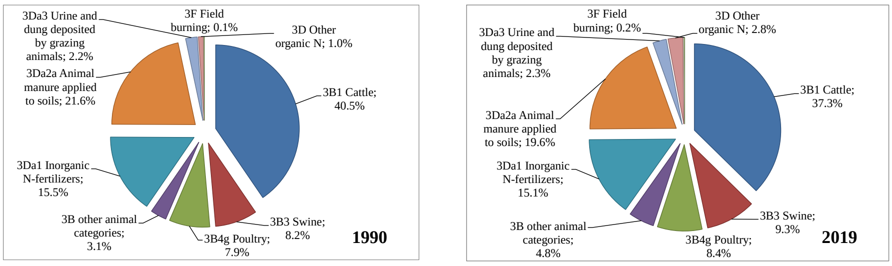

Figure 6.1 *Share of NH_3 emissions in the agriculture sector for 1990 and 2019*

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 to 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 for 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 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*

[1] The last census was conducted in 2010 and data are available at the link http://dati-censimentoagricoltura.istat.it/

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

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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	6,949,091	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	6,625,890	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	6,828,000	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	7,484,162	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	7,588,658	17,957,421	175,912,339	125,000
2011	1,754,981	4,142,544	354,402	7,942,641	959,915	373,327	50,966	7,602,093	17,549,225	174,787,108	160,000
2012	1,857,004	3,885,606	348,861	7,015,729	891,604	395,913	59,865	7,254,621	17,465,477	174,647,830	165,000
2013	1,862,127	3,984,545	402,659	7,181,828	975,858	393,915	63,166	7,111,607	16,548,690	176,919,056	170,000
2014	1,830,990	3,925,080	369,349	7,166,020	937,029	390,886	67,016	7,269,295	16,435,598	175,563,904	175,000
2015	1,826,484	3,954,864	374,458	7,148,534	961,676	384,767	70,872	7,266,945	15,760,502	177,391,671	180,000
2016	1,821,764	4,108,003	385,121	7,284,874	1,026,263	388,324	74,215	7,102,896	15,207,274	178,690,367	160,000
2017	1,791,120	4,158,273	400,792	7,215,433	992,177	367,561	72,455	7,185,630	14,000,931	178,635,180	180,000
2018	1,693,332	4,229,872	401,337	7,179,158	986,255	367,561	72,455	7,085,003	12,089,836	175,021,627	145,000
2019	1,643,117	4,331,830	402,286	7,000,880	1,058,720	367,561	72,455	7,098,664	10,873,698	175,520,313	145,000

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 SPA surveys (available for the years 2000, 2005, 2007, 2010, 2013 and 2016) were taken into account; 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 on the basis of 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 (ENEA, 2006).

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

Type of fertilizers	Emission factor	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
		Nitrogen content (t N yr^{-1})									
Ammonium sulphate	7.58%	50,762	61,059	36,698	27,855	32,568	16,986	18,064	16,174	16,624	10,267
Calcium cyanamide	1.32%	3,310	507	3,003	2,357	4,958	3,046	2,803	2,958	2,696	2,655
Nitrate (*)	1.29%	46,657	52,769	48,701	58,427	32,964	40,157	27,594	27,869	32,477	22,332
CAN	0.66%	112,565	139,253	112,541	109,445	71,261	51,200	52,159	51,848	55,804	44,102
Urea	13.09%	291,581	321,196	329,496	317,814	209,829	266,154	321,594	261,767	241,209	247,199
Other nitric nitrogen	1.32%	-	-	3,204	5,219	3,332	1,189	1,513	1,001	1,221	1,784
Other ammoniacal nitrogen	1.32%	-	-	6,278	18,069	12,412	7,035	8,423	6,868	7,460	7,335
Other amidic nitrogenous	13.09%	-	-	6,988	17,420	15,366	11,796	18,246	19,944	17,982	24,331
Phosphate nitrogen	5.52%	112,237	99,468	77,916	69,758	45,837	35,054	33,240	42,937	35,555	34,648
Potassium nitrogen	1.81%	3,937	2,876	5,291	12,289	15,955	9,077	13,361	10,503	10,751	7,922
NPK nitrogen	5.52%	138,018	101,528	113,897	106,384	64,462	50,174	49,829	47,416	45,749	36,686
Organic mineral	1.32%	444	20,960	38,688	34,809	19,085	25,986	20,385	33,555	27,477	27,581

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Type of fertilizers	Emission factor	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
		Nitrogen content (t N yr^{-1})									
Total		**759,510**	**799,614**	**782,701**	**779,846**	**528,029**	**517,854**	**567,211**	**522,840**	**495,005**	**466,842**

(*) includes ammonium nitrate < 27% and ammonium nitrate > 27% 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, 2019), the *2006 IPCC Guidelines* (IPCC, 1997; IPCC, 2006) and the *IPCC Good Practice Guidance* (IPCC, 2000). 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 Report/Common Reporting Format (NIR/CRF)* 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 to ammonia and factor 3.286 (= 46/14) was used to convert nitrous nitrogen to nitrogen dioxide.

6.2.1 **Manure management (3B)**

For 3B category, Italy has estimated emissions for pollutants recommended in the *2019 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 sectoral reports (APAT, 2005; Cóndor *et al.*, 2008; Cóndor, 2011), and 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, NOx, NMVOC), T1 (PM10, PM2.5)	NS	CS (NH_3, NOx), D (PM10, PM2.5), T2 (NMVOC)
3B4a, 3B2, 3B4d, 3B4e, 3B4f	Buffalo, Sheep, Goats, Horses, Mules and Asses	T2 (NH_3, NOx, NMVOC), T1 (PM10, PM2.5)	NS, IS	CS (NH_3, NOx), D (PM10, PM2.5), T2 (NMVOC)
3B3	Swine	T2 (NH_3, NOx, NMVOC), T1 (PM10, PM2.5)	NS	CS (NH_3, NOx), D (PM10, PM2.5), T2 (NMVOC)
3B4gi, 3B4gii, 3B4giii 3B4giv	Poultry	T2 (NH_3, NOx, NMVOC), T1 (PM10, PM2.5)	AS	CS (NH_3, NOx), D (PM10, PM2.5), T2 (NMVOC)
3B4h	Other	T2 (NH_3, NOx, NMVOC), T1 (PM10, PM2.5)	NS	CS (NH_3, NOx), D (PM10, PM2.5), T2 (NMVOC)

NS=national statistics; IS= International statistics (FAO); AS= category association statistics (UNAITALIA); CS=country-specific; D=Default (from 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 in two different fluxes, depending on whether animals are inside (housing, storage and manure application) or outside the stable (grazing). More in detail, part of the nitrogen excreted in housing volatilizes during the settle of manure in the local farming and it is calculated with the relevant emission factor in housing for the different livestock; this amount is therefore subtracted from the total nitrogen excreted to derive 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.

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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]): 5% for dairy cattle, 2.2% for other cattle, 2.9% for buffalo, 60% for equines, 90% for sheep and goats.

The excretion rates (CRPA, 2018; CRPA, 2006[a]; GU, 2006; Xiccato *et al*., 2005), slurry/solid manure production and average weights (CRPA, 2018; CRPA, 2006[a]; GU, 2006; Regione Emilia Romagna, 2004) were updated with country specific information. 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 2019*

Category	Weight *kg*	Housing *kg N head^{-1} yr^{-1}*	Grazing	Total
Non-dairy cattle	387.4	50.75	1.43	**52.18**
Dairy cattle	602.7	101.12	5.32	**106.44**
Buffalo	499.0	57.65	1.72	**59.38**
Other swine (*)	88.0	13.44	-	**13.44**
Sow (*)	172.1	28.55	-	**28.55**
Sheep	47.1	1.62	14.58	**16.20**
Goats	45.3	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	1.9	0.49	-	**0.49**
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 parameters digestibility (DE) of diet and methane conversion factor (Ym), 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 e Ym parameters, 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. On the basis of 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 reared. The difference in 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 for the production of 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

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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 2019, the percentages of dairy cows according to the three productivity levels are 77.2%, 12.3% and 10.5%. 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 68.6%. The weighted average value of Ym for the year 2019 is 5.9. This value was calculated from the percentage distribution of dairy cows according to the three productivity levels and using the default factors given in Table 10.12 of the 2019 IPCC Guidelines. These values are: 6.5 for low producing cows; 6.3 for medium producing cows; 6.0 and 5.7 for high producing cows. From these last two values, a weighted average value of 5.92 was calculated for the year 2019, with the distribution of cows according to diet type, shown above: 27% of high-productivity cows are associated with diets with DE≥70 and NDF≥35 (Ym 6.0); 73% of high-productivity cows are associated with diets with DE≥70 and NDF≤35 (Ym 5.7). As regards the percentage for protein in diet, mentioned above, on the basis of 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. This change results in a change in the nitrogen excreted by dairy cows (which is down from the previous submission).

In Table 6.5 the animal waste management system (AWMS) distribution and EFs used are reported. EF was multiplied by the percentage of the nitrogen excreted in housing equal to 95% of the total, assuming that 5% is excreted in grazing. The value is a weighted average based on country specific emission factors and the distribution of livestock housing 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 centre of Italy and on ISTAT statistics of 2003 and on 2010 Agricultural Census). Between 2005 and 2010 a gradual transition to the updated distribution of housing systems has been assumed for the intermediate years taking in account 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
Housing					
cubicle house: 14.3 N-NH_3 kg/head/year (Bonazzi et al, 2005)	14.6%	14.6%	14.6%	27.9%	27.9%
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%
tied cows: 12.9 N-NH_3 kg/head/year (Bonazzi et al, 2005)	76.2%	76.2%	76.2%	29.5%	29.5%
EF N-NH_3 kg/head/year	**13.4**	**13.4**	**13.4**	**14.5**	**14.5**
Storage					
liquid manure	liquid manure = 36%	liquid manure = 36%	liquid manure = 36%	liquid manure = 48%	liquid manure = 48%
Tanks (for liquid manure): 23% of N at storage (Bonazzi et al, 2005)	40.0%	75.5%	75.5%	82.3%	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%

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covered storage (for liquid manure):	10.0%	12.5%	12.5%	15.2%	28.3%
covered tanks high reduction: 4.6% (reduction of 80% compared to tanks)		1.0%	1.0%	3.0%	4.0%
covered tanks medium reduction: 9.2% (reduction of 60% compared to tanks)		1.0%	1.0%	3.0%	4.0%
covered tanks low reduction: 13.8% (reduction of 40% compared to tanks)	10.0%	10.5%	10.5%	8.9%	16.2%
biogas: no emission				0.33%(1)	4.1%(1)
solid storage: 14.2% of N at storage (Regione Emilia Romagna, 2001)	solid manure = 64%	solid manure = 64%	solid manure = 64%	solid manure = 52%	solid manure = 52%

(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 18% 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, 3% of manure went to digesters and 11% were covered digestate tanks; in 2013 these values become 15% and 27% respectively. This trend was assumed on the basis of 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 is 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] and 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 CRF (*Common Reporting Format* 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 the 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 on the basis of the ILF-BREF document (EC, 2003) with regards the covered storage (CRPA, 2006[a]).

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. On the basis of ISTAT statistics on storage systems as 2010 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 and 2010-2013) taking in account the gradual penetration of the abatement technologies.

On the basis of 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 the Table 6.8 for the year 2019.

Regarding emission factors for cattle, the evolution of different abatement technologies along 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.

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

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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 takes into account 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 in account the relevant emission factors of the abatement technologies for each manure system. The implemented abatement technologies for the years 1990, 2003 and 2005 are reported in Table 6.6.

Table 6.6 *Abatement technologies for the swine category*

Livestock category	1990	2003	2005	2010	2013
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; 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	Same distribution for the year 2005	Same distribution for the year 2005
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	Same distribution for the year 2005	Same distribution for the year 2005
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	Same distribution for the year 2005	Same distribution for the year 2005
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
Livestock category	**1990**	**2003**	**2005**	**2010**	**2013**
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:
covered tanks high reduction: reduction of 80% compared to tanks				1%	3%
covered tanks medium reduction: reduction of 60% compared to tanks		1%	1%	4%	5%

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Livestock category	1990	2003	2005	2010	2013
covered tanks low reduction: reduction of 40% compared to tanks	3%	2%	2%	6%	17%
biogas: no emission				0.33%(1)	0.81%(1)

Livestock category	1990	2003	2005	2010	2013	2016
Land spreading						
swine	100%	80% broadcasting 10% low efficiency 10% high efficiency	78% broadcasting 11% low efficiency 11% high efficiency	70% broadcasting 17% low efficiency 6% medium efficiency 7% high efficiency	48% broadcasting 30% low efficiency 12% medium efficiency 11% high efficiency	36% broadcasting 27% low efficiency 26% medium efficiency 11% high efficiency

(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 along 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]). Furthermore, an update of emission factors from manure storage and land spreading for swine category has been estimated on the basis of ISTAT statistics on manure storage systems and land spreading techniques such as 2010 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 and 2014-2016) taking in account the gradual penetration of the abatement technologies.

On the basis of 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 the laying hens is due to the evolution of different abatement technologies along 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] and 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 category*

Emission factors by manure management system	1990	2003	2005	2010
Housing				
open manure storage under cages (for liquid manure) (RS) = 0.220 kg NH3/head/year (EC, 2003)	100%	20%	11%	4%
deep pit = 0.162 kg NH3/head/year (ENEA, 2003)		24%		
vertical tiered cages with manure belts and forced air drying = 0.06 kg NH3/head/year (ENEA, 2003) [reduction in ammonia emissions of 73% compared to RS]		56%	74%	50%

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Emission factors by manure management system	1990	2003	2005	2010
vertical tiered cages with manure belt and whisk-forced air drying = 0.088 kg NH3/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 NH3/head/year (EC, 2003) [reduction in ammonia emissions of 30% compared to RS]			10%	11%
vertical tiered cages with manure belt and drying tunnel over the cages = 0.044 kg NH3/head/year (EC, 2003) [reduction in ammonia emissions of 80% compared to RS]			3%	
Loose housing with outdoor access (RS) = 0.3 kg NH3/head/year (Bittman S. et al, 2014)				7%
Loose housing without outdoor access = 0.18 kg NH3/head/year (Bittman S. et al, 2014; our assumptions)				28%
Storage				
liquid manure = 16% (percentage of nitrogen to storage) (Nicholson et al, 2004)	100%	20%	11%	4%
solid manure = 7.3% (ENEA, 2003)		80%	89%	96%
Land spreading				
liquid manure = 37.1% of TAN applied (TAN/TKN = 35%) (CRPA, 2006[a]) [broadcasting]	100%	5%	9%	9%
low efficiency = 7.8% (bandspreading and incorporation within 6 hours for liquid manure) [reduction of 40% compared to broadcasting]		50%	65%	65%
high efficiency = 2.6% (shallow and deep injection for liquid manure) [reduction of 80% compared to broadcasting]		45%	26%	26%
solid manure = 67% of TAN applied (TAN/TKN = 21%) (Nicholson et al, 2004; CRPA, 2006[a]) [broadcasting]		10%	9%	10%
low efficiency = 11.0% (incorporation within 12-24 hours for solid manure) [reduction of 20% compared to broadcasting]		40%	37%	43%
high efficiency = 2.8% (incorporation within 4 hours for solid manure) [reduction of 80% compared to broadcasting]		50%	54%	46%

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). In 2010, on the basis of the housing distribution collected from the 2010 Agricultural Census and emission factors and abatement systems data reported in the Guidance from the UNECE Task Force on Reactive Nitrogen (Bittman S. et al, 2014) emission factors have been updated. Between 2005 and 2010 a gradual transition to the updated distribution of housing systems has been assumed for the intermediate years taking in account the gradual penetration of systems to ensure animal welfare.

As regards the manure storage, emission factors are expressed as a percentage of the nitrogen contained in manure to storage. Emission factors used for liquid manure is derived from Nicholson et al (Nicholson et al, 2004) and emission factors for solid manure is from ENEA (ENEA, 2003). On the basis of the 2010 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) taking in account 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] and 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 improvements 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 on the basis of the UNECE document Control techniques for preventing and abating emissions of ammonia (as referenced in CRPA, 2006[a] and CRPA, 2006[b]). EFs for land spreading reported in Table 6.7 have been multiplied by the amount of nitrogen remaining after storage emissions.

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As regards broilers, only a slight improvement on spreading system has occurred. From 1995 a chicken-dung drying process system has been introduced for laying hens and improved along the period.

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

Regarding emission factors for poultry, the evolution of different abatement technologies along 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.

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 2019*

Category	**Housing**	**Storage**	**Land spreading**	**Grazing**	**Total**
			kg NH_3 head^{-1} yr^{-1}		
Non-dairy cattle	7.62	8.55	5.58	0.14	**21.89**
Dairy cattle	16.73	16.66	10.86	0.52	**44.76**
Buffalo	8.66	9.90	7.41	0.17	**26.13**
Other swine (*)	2.38	1.68	1.13		**5.19**
Sow (*)	4.86	3.59	2.42		**10.87**
Sheep	0.22		0.46	0.71	**1.38**
Goats	0.22		0.46	0.71	**1.38**
Horses	3.24		2.75	2.91	**8.90**
Mules and asses	3.24		2.75	2.91	**8.90**
Laying hens	0.13	0.05	0.05		**0.22**
Broilers	0.08	0.05	0.03		**0.15**
Turkeys	0.25	0.15	0.08		**0.48**
Other poultry	0.08	0.05	0.03		**0.16**
Rabbit	0.34	0.13	0.07		**0.54**
Fur animals	1.37		0.34		**1.70**

(*) 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, 2019). On the basis of 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 feed, livestock manure and nitrogen from manure treated by biogas facilities are shown in Table 6.9.

Table 6.9 *Total feed, animal manure and nitrogen in manure treated by biogas facilities*

Year	**Total feed (t)**	**Animal manure in total feed (t)**	**Nitrogen from animal manure (t)**
1990	-	-	-
1995	n.a.	273,863	1,444,160
2000	n.a.	165,670	872,748
2005	n.a.	1,078,548	5,420,330
2006	n.a.	1,915,473	10,049,297
2007	6,411,746	2,220,128	11,726,332
2008	5,863,026	1,891,768	9,887,578
2009	4,646,166	1,688,220	8,752,180
2010	6,513,271	1,766,348	8,604,830

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Year	Total feed (t)	Animal manure in total feed (t)	Nitrogen from animal manure (t)
2011	12,598,369	3,845,980	20,027,528
2012	15,466,667	7,080,141	37,792,788
2013	27,724,820	12,736,627	68,822,196
2014	30,933,617	14,201,573	76,766,300
2015	29,551,431	13,600,442	73,374,677
2016	29,711,711	13,672,393	73,705,652
2017	30,377,277	13,979,575	75,364,029
2018	30,311,196	13,950,253	75,246,663
2019	32,527,887	14,929,218	80,615,252

n.a.= not available

Because of multiple substrates fed to bio-digesters, the following average characteristics of the feed, reported in Table 6.10, as supplied by CRPA, are considered for the Italian bio-digesters in order 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

On the basis of 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 the 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 the spreading also includes the digestate.

For NO_X emissions (during storage) tier 2 method reported in the EMEP/EEA Guidebook (EMEP/EEA, 2019) was used for calculations. EFs by livestock category and manure type derived from the EMEP/EEA Guidebook (EMEP/EEA, 2019) 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, 2019). However, the emission factors are very high and therefore more detailed analyzes will be carried out. As requested during the 2020 NECD reviews (EEA, 2020), NMVOC emissions from turkeys are estimated and reported in the 3B4giii category.

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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, 2019; EMEP/CORINAIR, 2006), modified on the basis of the Italian animal breeding characteristics and weight parameters (Cóndor *et al*., 2008; Cóndor, 2011). For swine and poultry, emission factors have been updated from 2010, estimating a gradual transition to the updated emission factors from 2005, reflecting changes in manure management systems recorded by ISTAT surveys (FSS and the agricultural census). From 2010 PM emission estimates are based on emission factors provided by the 2019 EMEP/EEA Guidebook. These 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. A gradual transition to the updated emission factors has been assumed for the intermediate years (2004-2010) taking in account the gradual penetration of the abatement technologies. As requested during the 2020 NECD reviews (EEA, 2020), 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. Average emission factors for PM per head are reported in Table 6.12.

Table 6.12 *PM emission factors for manure management for the year 2019*

Category	PM10	PM2.5
	kg PM head^{-1} yr^{-1}	
Non-dairy cattle	0.318	0.210
Dairy cattle	0.657	0.428
Buffalo	0.504	0.329
Other swine (*)	0.190	0.008
Sow (*)	0.232	0.012
Sheep	0.053	0.016
Goats	0.051	0.015
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	0.034	0.006
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) and N fixed by cultivated crops, leguminous cultivation (3De). For the same sources, emissions of NO_X were estimated (except for 3De *Cultivated crops*). *Crop residues applied to soils* (3Da4) and *Indirect emissions from managed soils* (3Db) emissions 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, 2019), which provides different EFs by type of fertilizers taking into account climatic conditions 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. Emissions have been calculated on the basis of EFs for temperate climate and normal pH factors according to the IPCC climate zones classification and the definition available in the 2002 EMEP/CORINAIR Guidebook for which Italy is defined with large areas of acidic soils (soil pH below 7.0) and with some calcareous soils (or managed with soil pH above 7.0).

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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]; Cóndor and Valli, 2011).

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, 2019) 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, 2019).

The method for estimating NH_3 emissions from animal manure applied to soils (3Da2a) is described in 3B (tier 2). On the basis of ISTAT statistics on spreading systems such as 2010 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 and 2013-2016) taking in 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, 2019) 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, 2019).

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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 8 of the National Inventory Report 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 t 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 6.13, 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 NOx EF (0.04 kg NO_2/kg N applied) are from EMEP/EEA Guidebook (EMEP/EEA, 2019).

Table 6.13 *Sludge spreading activity data and parameters, 1990 – 2019*

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	5.2	5,071
1995	2,437,024	630,046	157,512	5.2	8,137
2000	3,402,017	869,696	217,424	5.0	10,954
2005	4,298,576	862,970	215,742	4.1	8,874
2010	3,697,625	992,859	248,215	4.0	10,040
2011	3,572,092	1,196,634	299,159	3.7	11,119
2012	3,446,558	1,096,380	274,095	4.7	12,864
2013	3,074,108	814,178	203,545	4.0	8,053
2014	3,154,060	804,623	201,156	4.1	8,301
2015	3,069,302	888,899	222,225	3.7	8,303
2016	3,183,919	765,639	191,410	3.9	7,410
2017	3,183,641	691,375	172,844	4.1	7,116
2018	3,137,372	693,434	173,358	4.2	7,247
2019	3,254,796	673,670	168,417	4.1	6,977

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

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the paragraph 6.1). The default NH_3 EF (0.08 kg NH_3/kg waste N applied) and NOx EF (0.04 kg NO_2/kg N waste applied) are from EMEP/EEA Guidebook (EMEP/EEA, 2019).

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, 2019). 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, 2019).

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 6.14, cultivated surface from N-fixing species (ha yr^{-1}) and N fixed by each species (kg N ha^{-1} yr^{-1}) are shown.

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, 2019). The default NMVOC EF is from EMEP/EEA Guidebook (EMEP/EEA, 2019). 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, 2019).

Table 6.14 *Cultivated surface (ha) and nitrogen fixed by each variety (kg N ha^{-1} yr^{-1})*

N fixed		**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2017**	**2018**	**2019**
kg N $ha^{-1}yr^{-1}$						ha				
Bean, f,s.	40	29,096	23,943	23,448	23,146	19,027	17,059	18,618	18,368	18,253
Bean, d.s.	40	23,002	14,462	11,046	8,755	7,001	5,870	6,001	6,411	5,587
Broad bean, f,s.	40	16,564	14,180	11,998	9,484	8,487	7,914	7,553	7,985	7,624
Broad bean, d.s.	40	104,045	63,257	47,841	48,507	52,108	42,157	51,135	50,421	60,007
Pea, f,s.	50	28,192	21,582	11,403	11,636	8,691	14,940	15,232	15,559	16,197
Pea, d.s.	72	10,127	6,625	4,498	11,134	11,692	11,181	17,046	17,916	22,926
Chickpea	40	4,624	3,023	3,996	5,256	6,813	11,167	20,025	26,024	20,999
Lentil	40	1,048	1,038	1,016	1,786	2,458	3,099	4,981	5,417	5,861
Vetch	80	5,768	6,532	6,800	7,656	8,000	8,230	8,230	8,230	8,230
Lupin	40	3,303	3,070	3,300	2,500	4,000	4,620	4,620	4,620	4,620
Soya bean	58	521,169	195,191	256,647	152,331	159,511	308,979	322,417	326,587	273,332
Alfalfa	194	987,000	823,834	810,866	779,430	745,128	667,325	682,160	695,492	719,073
Clover grass	103	224,087	125,009	114,844	103,677	102,691	119,942	118,390	124,375	127,087
Total		**1,958,025**	**1,301,746**	**1,307,702**	**1,165,298**	**1,135,606**	**1,222,483**	**1,276,409**	**1,307,405**	**1,289,796**

(*) f.s.=fresh seed; d.s.=dry seed

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, 2019). The default PM10 and PM2.5 EFs are from EMEP/EEA Guidebook (EMEP/EEA, 2019). Hectares of total arable crop surface have been used as activity data for PM emissions according to the methodology EMEP/EEA Guidebook (EMEP/EEA, 2019).

HCB emissions from the use of pesticides (3Df) have been estimated. HCB emissions result from the use of HCB as pesticide but also by the use of 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[3]). 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[4]. From

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

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

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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 on the basis of 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 from 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, 2019), which states all the HCB present as a contaminant will be volatilised, HCB emissions result in 118.82 kg for 1990 and 2.26 kg in 2018 for Italy (for 2019 updated data are not available yet). 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.

Detailed information on activity data sources, methods and EFs by pollutant for 3D category is shown in Table 6.15.

Table 6.15 *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			
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 (for heavy metals, PAH emissions and BC) approach. 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, CO, NMVOC, IPCC emission factors have been used (IPCC, 1997), while for PM10 and PM2.5 emission factors from the USEPA (EPA, 1995) and BC emission factors from the EMEP/EEA Guidebook (EMEP/EEA, 2019) have been applied. NH_3, SO_2, heavy metals, dioxin and PAH emission factors are from the EMEP/EEA Guidebook (EMEP/EEA, 2019).

As concerns NO_X and CO emission factors, values used are in the range of the tier 1 emission factors from the EMEP/EEA Guidebook (EMEP/EEA, 2019).

As concerns PM emission factors, values used are higher than those (both tier 1 and tier 2) reported in the EMEP/EEA Guidebook (EMEP/EEA, 2019). The tier 1 emission factors from EMEP/EEA Guidebook are similar but not equal to the average of the values relating to four types of crops reported in the reference

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scientific publication mentioned in the Guidebook (Jenkins, 1996a). However for field burning of rice cultivation, the emission factor reported in the Guidebook is very different from that in the reference publication of Jenkins. Also in consideration of these issues emission factors have not been changed with those of the Guidebook and further work is planned with the aim to find values more representative of our country.

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 2019 the sector accounts for:

- 94.3% of national total NH_3 emissions
- 21.6% of national total HCB emissions
- 14.1% of national total NMVOC emissions
- 13.3% of national total PM10 emissions
- 7.8% of national total NO_X emissions
- 3.8% of national total PM2.5 emissions
- 2.6% of national total Cd emissions

Moreover, the sector comprises 0.6% of BC emissions, 0.6% of CO, 0.5% of PAH, 0.3% of Hg, 0.16% of As, 0.12% of Se, 0.07% of SO_2, 0.07% of Cr, 0.04% of Dioxins, 0.04% of Ni, 0.02% of Zn and 0.01% of Pb, 0.01% of Cu. There are no particular differences as compared to the sectoral share in 1990 when the agriculture sector accounted for 96.2% of NH_3 emissions, 11.1% of PM10, 3.1% of PM2.5, except for NMVOC emissions (4.7%), NO_X emissions (2.9%) and HCB emissions where agriculture accounted for 85.2% of total national emissions.

Table 6.16 reports the key categories identified in the agriculture sector while the time series of NH_3 emissions by sources is shown in Table 6.17.

Concerning NH_3 emissions, the category *manure management (3B*) represents in 2019 56.4% of national total ammonia emissions (57.3% in 1990). In particular, NH_3 emissions from *cattle* (3B1) stand for 62.4% of 3B emissions, while emissions from *swine* (3B3) and *poultry* (3B4g) represent 15.6% and 14.0%, respectively. The category *agricultural soils (3D*) represents in 2019 37.7% of national total ammonia emissions (38.8% in 1990). The animal manure applied to soils (3Da2a) and the use of synthetic N-fertilisers (3Da1) represent 49.1% and 37.7% of 3D emissions, respectively.

Regarding PM10 emissions, the category *manure management (3B*) accounts for 6.1% in 2019 (6.1% 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 56.6%, 23.5% and 13.1%, respectively. The category Farm-level agricultural operations including storage, handling and transport of agricultural products (3Dc) accounts for 6.0% in 2019 (4.3% in 1990) of national total PM10 emissions. For PM2.5 emissions, the category *manure management* (3B) contributes for 2.0% in 2019 (1.9% in 1990) of national total PM2.5 emissions. *Cattle* (3B1) accounts for 58.9%, while *poultry* (3B4g) stands for 27.0% 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 2019 (0.2% in 1990) of national total PM2.5 emissions.

Concerning NO_X emissions, the category *manure management (3B*) represents in 2019 0.26% of national total NO_X emissions (0.09% in 1990). For NO_X emissions, the category *agricultural soils* (3D) contributes for 7.4% in 2019 (2.8% in 1990) of national total NO_X emissions. *Inorganic N-fertilizers* (3Da1) and *Animal manure applied to soils* (3Da2a) account for 40.1% and 39.5% of total 3D emissions, respectively.

For NMVOC emissions, the category *manure management* (3B) and *agricultural soils* (3D) contributes for 81.5% and 18.1% in 2019 of agricultural NMVOC emissions. C*attle* (3B1), *poultry* (3B4g) and *buffalo* (3B4a) represent the major contributors to the total NMVOC emissions from category 3B with 74.1%, 15.1% and 4.9%, respectively. Most of the emissions in the 3D category derive from *Animal manure applied to soils* (3Da2a).

Table 6.16 *Key categories in the agriculture sector in 2019*

	SO_X	NO_X	NH3	NMVOC	CO	PM10	PM2.5	BC	Pb	Cd	Hg	PAH	DIOX	HCB	PCB
%															
3B1a		0.06	15.47	4.18		0.63	0.50								

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	SO$_X$	NO$_X$	NH3	NMVOC	CO	PM10	PM2.5	BC	Pb	Cd	Hg	PAH	DIOX	HCB	PCB
%															
3B1b		0.08	19.75	4.35		0.80	0.65								
3B2		0.02	0.43	0.10		0.21	0.08								
3B3		0.00	8.81	0.35		0.80	0.04								
3B4a		0.01	2.10	0.57		0.12	0.10								
3B4d		0.00	0.07	0.01		0.03	0.01								
3B4e		0.01	0.34	0.11		0.05	0.04								
3B4f		0.00	0.07	0.01		0.01	0.00								
3B4gi		0.02	1.95	0.25		0.74	0.07								
3B4gii		0.02	3.63	0.60		1.43	0.18								
3B4giii		0.01	1.54	0.35		0.87	0.20								
3B4giv		0.01	0.76	0.53		0.41	0.09								
3B4h		0.01	1.51	0.10		0.00	0.00								
3Da1		2.98	14.21												
3Da2a		2.94	18.52	1.76											
3Da2b		0.04	0.26												
3Da2c		0.54	1.91												
3Da3		0.93	2.40	0.01											
3Dc						5.96	0.28								
3De			0.44	0.77											
3Df														21.63	
3F	0.07	0.07	0.16	0.07	0.58	1.24	1.53	0.63	0.01	2.65	0.32	0.55	0.04		

Note: key categories are shaded in blue

Table 6.17 *Time series of ammonia emissions in agriculture (Gg)*

NFR SECTOR 3	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
3B1a Manure management - Dairy cattle	93.01	75.36	70.63	62.33	60.11	60.07	60.05	59.47	56.47	54.86
3B1b Manure management - Non-dairy cattle	88.77	86.70	84.62	73.92	71.45	66.82	69.87	70.52	72.27	70.06
3B2 Manure management - Sheep	1.91	2.33	2.42	1.74	1.73	1.56	1.59	1.58	1.57	1.53
3B3 Manure management - Swine	36.65	35.01	35.56	37.05	34.61	32.08	31.42	31.72	31.21	31.26
3B4a Manure management - Buffalo	3.06	4.53	5.79	6.40	10.34	7.88	7.71	7.99	7.95	7.47
3B4d Manure management - Goats	0.28	0.30	0.30	0.21	0.21	0.21	0.22	0.22	0.22	0.23
3B4e Manure management - Horses	0.93	1.02	0.91	0.90	1.21	1.25	1.26	1.19	1.19	1.19
3B4f Manure management - Mules and asses	0.27	0.12	0.11	0.10	0.15	0.23	0.24	0.23	0.23	0.23
3B4gi Manure management - Laying hens	13.87	12.68	9.56	6.30	7.84	7.03	6.98	7.08	6.88	6.93
3B4gii Manure management - Broilers	12.37	12.96	12.17	11.77	12.00	12.85	12.83	13.06	12.82	12.89
3B4giii Manure management - Turkeys	7.30	7.24	7.18	5.42	6.08	5.80	5.46	5.46	5.46	5.46
3B4giv Manure management - Other poultry	1.76	4.06	3.15	4.62	2.27	2.97	3.53	2.94	2.79	2.69
3B4h Manure management - Other animals (*)	7.51	8.41	8.79	10.00	8.69	7.72	7.43	6.89	5.93	5.35
3Da1 Inorganic N-fertilizers (includes also urea application)	69.58	72.51	72.33	70.69	48.27	53.30	62.94	54.13	50.00	50.40
3Da2a Animal manure applied to soils	97.06	89.03	81.23	71.89	69.68	66.01	66.23	66.54	65.85	65.70
3Da2b Sewage sludge applied to soils	0.66	1.06	1.42	1.15	1.31	1.08	0.96	0.93	0.94	0.91

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NFR SECTOR 3	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
3Da2c Other organic fertilisers applied to soils (including compost)	1.32	1.45	1.81	1.78	3.29	4.68	4.58	7.02	5.64	6.77
3Da3 Urine and dung deposited by grazing animals	10.09	11.33	11.48	8.74	8.97	8.60	8.79	8.65	8.60	8.51
3De Cultivated crops	2.38	1.58	1.59	1.42	1.38	1.48	1.50	1.55	1.59	1.57
3F Field burning of agricultural residues	0.49	0.48	0.48	0.52	0.50	0.51	0.55	0.49	0.53	0.58
Total	**449.23**	**428.17**	**411.52**	**376.93**	**350.09**	**342.13**	**354.12**	**347.64**	**338.12**	**334.59**

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%, 76% and 84% 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.

The reduction of NH_3 emissions from 3B is mainly related to the reduction in the number of animals. Between 1990 and 2019 total NH_3 emissions from 3B have reduced by 26.1%. Cattle livestock decreased by 22.9% (from 7,752,152 to 5,974,947 heads). Dairy cattle and non-dairy cattle have decreased by 37.8% and 15.2%, 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). On the contrary, swine and poultry have increased between 1990 and 2019 by 2.2% and 1.3%, respectively (see Table 6.1). 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 have allowed us to collect information on the inclusion of abatement technologies in Italy, especially those related to the swine and poultry recovery and treatment of manure and to land spreading (CRPA, 2006[b]; Cóndor et al., 2008; CRPA, 2010[b]).

NH_3 emissions of 3D category are driven by the animal manure applied to soils and the use of inorganic N-fertilizers. Between 1990-2019 emissions have respectively decreased by 32.3% and 27.6% mainly due to the reduction of the number of animals and the use of inorganic N-fertilizers, that are decreased overall by 38.5% (the urea decreased by 15.2%), in terms of nitrogen content. According to the Italian Fertilizer Association (AIF, *Associazione Italiana Fertilizzanti*) the use of fertilisers is determined by their cost and particularly by the price of agricultural products. Because of the agriculture product price decreasing, minor amount of fertilisers has been used by farmers to reduce costs (Perelli, 2007). 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 5 years the national emission inventory is disaggregated at NUTS3 level as requested by CLRTAP (Cóndor *et al*., 2008). A database with the time series for all sectors and pollutants has been published (ISPRA, 2018; ISPRA, 2009; ISPRA, several years [c]; ISPRA, several years [d]). The disaggregation of 2015 agricultural emissions has also been finalised and figures are available at the following web site: http://www.sinanet.isprambiente.it/it/sia-ispra/inventaria. The disaggregation (NUTS3) of the NH_3 agricultural emissions is shown in Figure 6.2. In 2015, four regions contributed with more than 60% of agricultural NH_3 emissions: Lombardia, Veneto, Emilia Romagna and Piemonte.

Codice campo modificato

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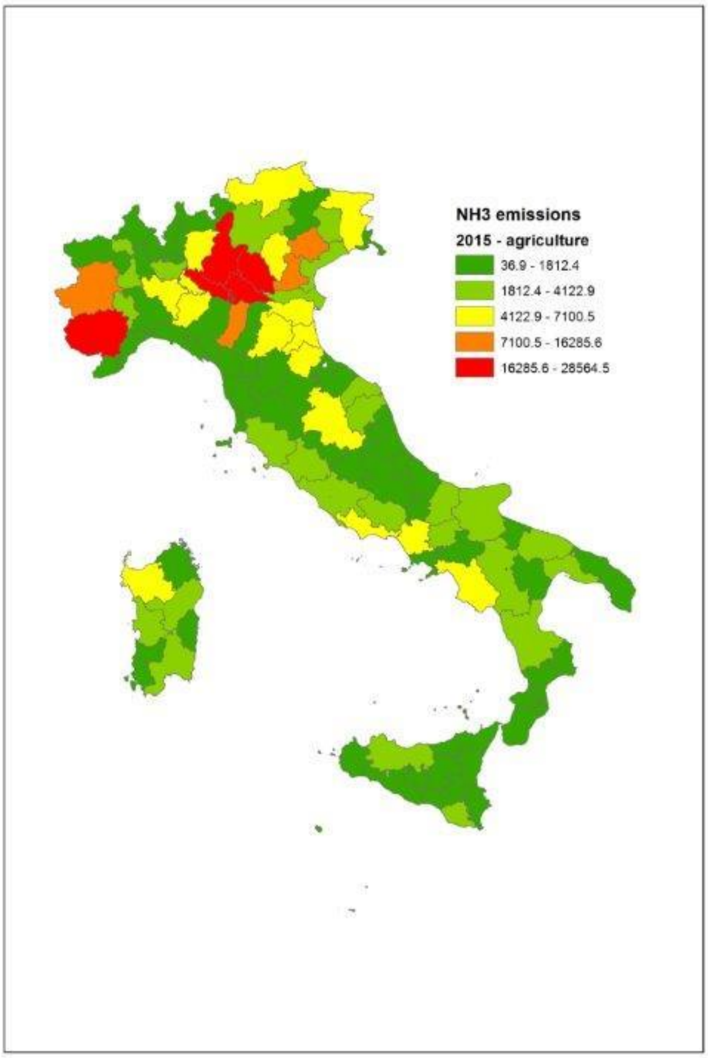

Figure 6.2 *NH_3 emissions from Agriculture in 2015 (t)*

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, feedbacks for the agricultural emission inventory derive also from communication of data to different institutions (ISTAT, UNA, CRPA etc.) and/or at local level (regional environmental institutions). In addition, ISPRA participates in a

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technical working group on agriculture within the National Statistical System, composed by producers and users of agricultural statistics.

Data used to estimate emissions were verified with census data. Slight differences in the livestock number (cattle and other swine) are found between conjunctural surveys (used for emissions estimation) and Agricultural Census for the year 2010; while for the other categories the differences are more significant. In the conjunctural surveys, the number of heads of the sows, sheep, goats, mules and asses, broilers, laying hens categories is on average 15% higher than the census, whereas for other poultry the difference is 30% and for horses and rabbits is more than double.

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 2014, which represent 62.1% and 19.5%, respectively, of national NH3 emissions for the same categories (3B).

Data on national sales of synthetic nitrogen fertilizers (by type of fertilizers) as provided by *Assofertilizzanti – Federchimica*[5] (personal communication) for the period 2012-2016 have been compared to official statistics provided by ISTAT. Differences were mainly found for the amount of simple mineral nitrogen fertilizers, where data from *Assofertilizzanti* are higher by 20%, on average, for the years 2013-2016. This could be due to a possible double counting of some product which could be considered as a single product and as a compound with other fertilizers. Further investigations will be conducted.

A check on the urea data has been made. Yara, the only Italian producer, provided an estimate of urea consumption in the various production sectors, such as SCR engines, NOx emissions reduction, industrial and agricultural uses. All these uses have been considered in the national emissions inventory. Further checks will be made between apparent consumption and end uses.

6.7 RECALCULATIONS

In 2021, recalculations were implemented for the agricultural emission inventory.

Updating the GE estimate of dairy cows from 2014, related to methane emissions from enteric fermentation, results in a change in excreted nitrogen from dairy cows, which changes NH_3, NO_2 and NMVOC emissions from manure management and soils. As already mentioned, changing the crude protein in the diet of dairy cows from 2000 involves changing the excreted N.

Data on the number of broilers and laying hens in the period 2001-2009 and since 2011 have been updated.

Updated data on N excreted for turkeys since 2007. As recommends during the 2020 NECD review (EEA, 2020), NMVOC and PM estimation for turkeys, previously included in the category other poultry, carried out.

Based on the comparison with ASSOFERTILIZZANTI and ISTAT experts on the historical series of synthetic fertiliser use, the nitrate data in the years 2009-2011 were revised. In addition, nitrate data (quantity and nitrogen content) were recalculated for the entire time series to include the estimated CAN fertiliser and therefore the NH_3 emissions were changed.

Other minor changes were: updating of the NH_3 estimate from manure spreading of buffalo category for the years 2010-2018; updating of the cattle and buffalo category effluent and field nitrogen production coefficients (which also implies the change in liquid and solid nitrogen percentages) for the years 2007-2015 and 2017-2018 (the change in nitrogen allocation % changes the estimate of NO_2 from manure management); the weight and excreted nitrogen coefficient of other poultry for the years 2007-2015; the excreted nitrogen coefficient for buffalo and calves from 2007 to 2015; update of the PM emission factor estimate for other poultry for the years 1990-2014 following update of the average weight of the category considered; updating of the NH_3 estimate from anaerobic digesters since 1991; the corrected value of nitrogen in legumes for 2018; sewage sludge data updated from 2016; the rice production figures for 2017 and 2018 have been updated; corrected NMVOC estimation errors for 2016 and 2017, PM2.5 for 2016, BC for 2017, SO_2 for 2018, NH_3 for 2018 for field burning of agricultural residues.

Corrected PM10 emission factor for fur animals since 1990.

As result from the 2020 NEC review, the HCB emissions from the use of pesticides have been revised.

[5] *Federchimica* is the National Association of the Chemical Industry and *Assofertilizzanti* represents the production companies of the fertilizer industry.

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6.8 PLANNED IMPROVEMENTS

Currently, uncertainty analysis, for the agricultural emission sector, is carried out only for the GHG emission inventory. We plan to estimate uncertainties also for the other pollutants, including NH_3 and PM. Monte Carlo analysis has also been performed for one key category of the GHG agricultural emission inventory; initial results are shown in the NIR (ISPRA, several years [a]).

No emissions are estimated for 3Da4 *Crop residues applied to soils*, 3Db *Indirect emissions from managed soils* and 3Dd *off-farm storage, handling and transport of bulk agricultural products*. However, Italy will assess the availability of AD and EFs for these categories.

In the coming years, the Permanent census of agriculture will provide valuable information on animal and agronomic production methods. The focus of the Permanent census is to provide a comprehensive information framework on the structure of the agricultural system and the livestock at national, regional and local level by integrating archive data and carrying out statistical support surveys. Statistical registers will be created with the aim of increasing the quantity and quality of information in order to reduce the response burden and the overall production cost of official statistics.

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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. From the previous submission, PM emissions from the category 5A and dioxins from the category 5E have been also estimated. Conversely, Italy does not consider NH_3 emissions from latrines because this activity does not occur or it can be considered negligible. 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	Waste water treatment in industry Waste water treatment in residential and commercial sector
5E	Other waste		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*

Main pollutants	5A	5B	5C1a	5C1bi	5C1bii	5C1biii	5C1biv	5C2	5C1bv	5D	5E
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									
Particulate matter											
TSP	x		x	x	x	x	x	x	x		x
PM10	x		x	x	x	x	x	x	x		x
PM2.5	x		x	x	x	x	x	x	x		x
BC			x	x	x	x	x	x	x		x
Priority heavy metals											
Pb			x	x	x	x	x	x	x		
Cd			x	x	x	x	x	x	x		
Hg			x	x	x	x	x		x		
POPs Annex II											

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Main pollutants	5A	5B	5C1a	5C1bi	5C1bii	5C1biii	5C1biv	5C2	5C1bv	5D	5E
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 2019, *open burning of waste* (5C2) is key category for Cd and BC. In 1990, *municipal waste incineration* (5C1a) and industrial waste incineration (5C1 bi) are key categories for dioxins emissions whereas *open burning of waste* (5C2) is key category for Cd. As regard the trend, *municipal waste incineration* (5C1a) is key category for dioxins emissions, *biological treatment of waste* (5B2) is key category for NH_3 emissions, 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 2019, the sector accounts for:

- 11.9 % in national total Cd emissions;
- 5.3 % in national total BC emissions;
- 4.7 % in national total Dioxin emissions;
- 4.2% in national total HCB emissions.

Moreover, the sector comprises 4.0% of total SO_2 emissions, 2.0% of total NH_3 emissions, 2.1% of CO, 2.0% of PAH, 1.8% and 1.7% in national total of PM2.5 and PM10 emissions respectively and for what concerns all remaining pollutants are below 1%.

7.2 METHODOLOGICAL ISSUES

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 Report on the Italian greenhouse gas inventory (ISPRA, 2020 [a]).

Following the suggestion of NEC review (EEA, 2017 [a]) more info about the extraction and use of biogas is provided below.

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 the following scheme consumptions and low calorific values are reported for the year 2019.

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1A4a biomass detailed activity data. Year 2019

Fuels		***Consumption (Gg)***	***LCV (TJ/Gg)***
Wood and similar	*Wood*	283.92	10.47
	Steam Wood	0.00	30.80
Incinerated waste (biomass)		2197.56	11.34
Biogas from landfills		258.22	54.52
Biogas from wastewater plants		25.94	54.52

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 system 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 2019, the non-hazardous landfills in Italy disposed 6,283 kt of MSW and 3,256 kt of industrial wastes, as well as 257 kt of sludge from urban wastewater treatment plants.

In Table 7.2, the time series of AMSW and domestic sludge disposed into non-hazardous landfills from 1990 is reported.

Table 7.2 *Trend of MSW production and MSW, AMSW and domestic sludge disposed in landfills (Gg)*

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ACTIVITY DATA (Gg)	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
MSW production	22,231	25,780	28,959	31,664	32,479	29,524	30,112	29,572	30,158	30,079
MSW disposed in landfills for non-hazardous waste	17,432	22,459	21,917	17,226	15,015	7,819	7,432	6,927	6,496	6,283
Assimilated MSW disposed in landfills for non-hazardous waste	2,828	2,978	2,825	2,914	3,508	3,222	2,513	3,899	3,512	3,256
Sludge disposed in managed landfills for non-hazardous waste	2,454	1,531	1,326	544	346	387	378	342	261	257
Total Waste to managed landfills for non-hazardous waste	16,363	21,897	26,069	20,684	18,870	11,428	10,322	11,167	10,269	9,797
Total Waste to unmanaged landfills for non-hazardous waste	6,351	5,071	0	0	0	0	0	0	0	0
Total Waste to landfills for non-hazardous waste	22,714	26,968	26,069	20,684	18,870	11,428	10,322	11,167	10,269	9,797

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 2019 (from 283,879 Mg to 6,900,552 Mg for composting and from 0 to 80,615 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 (MATTM, 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).

NH_3 emissions from biogas facilities (anaerobic digesters) in the agriculture sector have been updated on the basis of the study carried out by CRPA (CRPA, 2018) and in particular data relative to the percentages of the different substrates that feed the anaerobic digesters and data relative to the average content of volatile solids by type of substrates have been changed. As a result of these changes, the amount of manure sent to the digesters decreases considerably and also the NH_3 emissions. 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). On the basis of 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 historical series was updated. The ammonia emission factor has been updated to that contained in the 2019 Guidebook. Other minor changes that affects the estimation of the quantity of manure treated by biogas facilities were: data on the number of broilers and laying hens in the period 2001-2009 and since 2011 have been updated; the coefficients of cattle manure production and the weight of the category other poultry (which affects the coefficient of manure produced) for the years 2007-2015 have been updated; errors in the estimation of slurry and solid manure coefficients of other cattle were corrected.

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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, 2016).

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 2019, about 99% of the total amount of 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 7.3, 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 EF comes from table 3-1 of the 2019 EMEP/EEA Guidebook considering an abatement efficiency of 90% while PCB EF derives from 2007GB but considering 90% abatement (no value in the 2019 GB). For 5C1biii the EF from 2019GB have been used for PCB while HCB EF derives from 2007 GB because of a lack of information in the last guidebook. For 5C1biv EFs from 2019GB have been considered without abatement because information about this specific category of plant are under investigation. The results of the survey should be ready for the 2022 submission.

Table 7.3 *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	7.40	7.40	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	0.70	25.68	25.68	180.00	41.00	240.00	0.07
PM2.5	*g/t*	46.00	6.06	240.00	0.40	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

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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
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	-	-

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 7.4 dioxin emission factors for waste incineration are reported for 1990 and 2019.

Table 7.4 *Dioxin emission factors for 1990 and 2019*

Waste Typology	u.m	1990	2019
Municipal	g/t	115 - 1.6	0.1
Clinical	g/t	200	0.5
Industrial	g/t	80 - 135	0.5
Sludge	g/t	77	0.5
Oil	g/t	200	0.5

In Table 7.5 activity data are reported by type of waste.

Table 7.5 *Amount of waste incinerated by type (Gg)*

Waste incinerated	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
Total waste	1,656.2	2,149.1	3,061.7	4,964.2	6,977.3	7,534.7	7,587.7	7,477.2	7,726.0	7,753.2
with energy recovery	911.2	1,557.8	2,749.7	4,720.6	6,795.9	7,431.5	7,501.1	7,386.3	7,664.8	7,685.1
without energy recovery	745.0	591.3	312.0	243.5	181.4	103.2	86.7	91.0	61.1	68.1
Municipal waste (5C1a)	1,025.6	1,436.6	2,324.9	3,219.9	4,336.9	4,698.4	4,453.9	4,325.1	4,577.3	4,395.1
with energy recovery	626.4	1,185.5	2,161.4	3,168.0	4,284.0	4,698.4	4,453.9	4,325.1	4,577.3	4,395.1
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	2,505.3	2,734.7	3,029.1	3,051.9	3,041.2	3,246.9
with energy recovery	259.5	331.2	511.6	1,447.0	2,399.4	2,676.1	2,988.0	2,999.1	2,996.1	3,195.5
without energy recovery	236.6	229.6	114.8	171.1	105.9	58.6	41.1	52.8	45.1	51.5
Clinical waste (5C1biii)	134.5	151.7	110.3	126.2	135.1	101.6	104.7	100.2	107.5	111.1
with energy recovery	25.3	41.1	76.7	105.7	112.5	57.0	59.1	62.0	91.5	94.5

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Waste incinerated	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
without energy recovery	109.2	110.6	33.6	20.5	22.6	44.6	45.5	38.2	16.1	16.6

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, 2019).

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. For some metal, such as Pb, Cd, As, Cr, Cu, Ni and Se EFs are those reported in the Guidebook 2019.

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, the number of cremations in Italy has risen from 5,809 in 1990 to 194,669 in 2019. Moreover, it is practice to cremate 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 7.6 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. In Table 7.7 emission factors for cremation are reported.

Table 7.6 *Cremation time series (activity data)*

Cremation of corpses	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Cremations	5,809	15,436	30,167	48,196	77,379	137,168	141,555	170,903	183,146	194,669
Deaths	543,700	555,203	560,241	567,304	587,488	653,000	615,261	649,061	633,133	647,000
Mortal remains	1,000	1,750	1,779	9,880	18,899	34,178	36,608	36,425	37,538	38,305
% of cremation	1.07	2.78	5.38	8.50	13.17	21.01	23.01	26.33	28.93	30.09
Crematoria	ND	31	35	43	53	70	75	79	83	85

Table 7.7 *Emission factors for cremation of corpses*

Air pollutant	u.m.	Cremation
NO_X	kg/body	0.4238
CO	kg/body	0.0398
NMVOC	kg/body	0.0091
SO_X	kg/body	0.0234
PM10	g/body	2.93
PM2.5	g/body	2.93
Pb	mg/body	30.03
Cd	mg/body	5.03
Hg	mg/body	0.0059
As	mg/body	13.61
Cr	mg/body	13.56
Cu	mg/body	12.43
Ni	mg/body	17.33
PAH (benzo(a)pyrene)	µg/body	38.90
Dioxins	µg/body	0.0322

7.2.5 Small scale waste burning (5C2)

The open burning of agricultural waste is a key category for Cd emissions. Dioxins, TSP, PM10, PM2.5, BC, CO, NMVOC, PAH, SO_X, NO_X and heavy metals emissions have been estimated. No estimations were performed for NH_3 emissions as well as other POPs.

A country-specific methodology has been used. Parameters taken into consideration are the following:

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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 default emissions rate for $C\text{-}CH_4$, equal to 0.005 (IPCC, 1997).
6. C-CO from removable residues burning (t C-CO), calculated with the amount of carbon from removable residues burning release in air and default emissions rate for C-CO, equal to 0.06 (IPCC, 1997).
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 the default emissions rate for N- NO_X, equal to 0.121 (IPCC, 1997).

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 7.8).

Table 7.8 *Emission factors for burning of agriculture residues*

Air pollutant	u.m.	Removable residues				References
		Wheat – Barley – Rice – Orchards				
Benzo(a)pyrene	g/t	67.7	98.8	19	1.5	EMEP/EEA, 2016
Benzo(b)fluoranthene	g/t	189.1	307.4	31.5	2.8	
Benzo(k)fluoranthene	g/t	80.7	77	23.1	6.2	
Indeno(1,2,3-cd)pyrene	g/t	57.9	38.2	14.5		
PM10	g/t	3.3				EMEP/CORINAIR, 2007
PM2.5	g/t	2.8				EMEP/CORINAIR, 2007
Dioxins	g/t	10				EMEP/CORINAIR, 2016
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 7.9. 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.

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Table 7.9 *Time series of crop productions (Gg)*

Production	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					Gg					
Cereals										
Wheat	8,108.5	7,946.1	7,427.7	7,717.1	6,849.9	7,394.5	8,037.9	6,966.5	6,932.9	6,576.6
Rye	20.8	19.8	10.3	7.9	13.9	13.2	13.2	11.1	10.6	12.5
Barley	1,702.5	1,387.1	1,261.6	1,214.1	944.3	955.1	988.3	984.3	1,010.3	1,072.4
Oats	298.4	301.3	317.9	429.2	288.9	261.4	260.8	229.0	243.4	238.1
Rice	1,290.7	1,320.9	1,245.6	1,444.8	1,574.3	1,505.8	1,598.0	1,516.0	1,480.9	1,498.1
Maize	5,864	8,454	10,140	10,428	8,496	7,074	6,839	6,048	6,179	6,259
Sorghum	114.2	214.8	215.2	184.9	275.6	294.2	313.8	240.7	293.9	312.4
Woody crops										
Grapes	8,438.0	8,447.7	8,869.5	8,553.6	7,839.7	7,915.0	8,044.1	7,169.7	8,513.6	7,862.9
Olives	912.5	3,323.5	2,810.3	3,774.8	3,117.8	2,732.9	2,016.0	2,598.5	1,953.5	2,194.1
Citrus Orchards	2,868.8	2,607.7	3,100.2	3,518.1	3,820.6	3,151.5	2,766.4	2,811.3	2,631.3	2,895.9
Orchards	5,793.5	5,406.6	5,952.2	6,034.5	5,777.3	5,988.8	5,927.5	5,360.3	5,608.0	5,318.0
Carobs	29.2	44.4	38.1	31.7	25.3	31.5	28.9	28.9	37.0	35.9
Total	***35,441***	***39,474***	***41,388***	***43,339***	***39,023***	***37,318***	***36,834***	***33,965***	***34,894***	***34,276***

7.2.6 **Wastewater treatments (5D)**

The biogas collected from the anaerobic digestion of wastewaters is burned with heat/energy recovery and relevant emissions are reported in the energy sector. As regards NMVOC emissions from wastewater handling, consequently to the NECD review (EEA, 2017 [a]) At present, no reliable EFs are available for wastewater treatment plants at national level. By using EFs from the 2019 EEA/EMEP Guidebook both for domestic and industrial wastewater and the volumes of wastewater produced NMVOC emissions resulted in the time series reported in the table below (Table 7.10)

Table 7.10 *Time series of NMVOC emissions (Gg)*

	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
					NMVOC (Gg)					
Industrial wastewater	0.0136	0.0139	0.0138	0.0130	0.0108	0.0099	0.0104	0.0104	0.0106	0.0105
Domestic wastewater	0.0636	0.0821	0.0898	0.1005	0.1052	0.1030	0.1170	0.1189	0.1209	0.1228
Total	**0.0772**	**0.0961**	**0.1036**	**0.1135**	**0.1160**	**0.1129**	**0.1275**	**0.1293**	**0.1315**	**0.1333**

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). In the current submission, because EFs for house fires from Aasestad are given by scaling the emission factors used for combustion of fuelwood in the households, so referring prevalently to wooden houses, activity data have been

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updated consequently and taking into account only fires that involved wood, cork and wooden load-bearing structures as reported in the (Annually statistics of fire service in Italy, several years). 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 Tab. 7.11. On the basis of the last review reports (EEA, 2019; EEA, 2020) PCDD/F emissions have been estimated and revised. After the technical correction during the 2019 NECD review, Italy investigated EF because those reported in the guidebook seems to be unreliable or not fitting to the Italian context. In particular, the EF 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. The PCDD/DF EF is scaled in the same way as the PM, in fact the values indicated in the Guidebook for PM and dioxins are identical (except for the units of measurement) despite the dioxins factor, derived from (SFT 2001a), is clearly not comparable with that of the PM. Further, the EF reported in (SFT 2001a), equal to 170 µg I-Teq/Mg burned material, as reported in the same source, "can't be considered as default emission factors because only a small data base is available and the emission factors calculated from it have a broad range." Italy, given the inadequacy of the proposed emission factors, has decided to keep its own estimates and carry out in-depth studies also in relation to the consequences that a correction of this kind (5E would become a key category for PCDD/DF) should have on policies and measures on pollution prevention and control.

Table 7.11 *PM2.5 and BC emissions from the category 5E*

	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
Detached house fires (n°)	1252	1257	1268	1288	1044	1214	1289	1664	1287	1287
Undetached house fires (n°)	969	972	981	997	785	1456	1546	1995	1543	1543
Apartment building fires (n°)	2230	2239	2259	2294	2140	2952	3134	4043	3128	3128
Industrial building fires (n°)	583	586	591	600	517	618	982	976	478	478
Car fires (n°)	25867	25971	26203	26614	22735	22680	22696	23537	22761	22761
5E PM2.5 (Gg)	0.413	0.414	0.418	0.425	0.359	0.463	0.497	0.620	0.483	0.483
5E BC (Gg)	0.076	0.077	0.077	0.079	0.066	0.086	0.092	0.115	0.089	0.089
5E PCDD/F (g Iteq)	4.783	4.803	4.845	4.921	4.162	5.206	5.548	6.805	5.408	5.408

7.3 TIME SERIES AND KEY CATEGORIES

The following Table 7.12 presents an outline of the weight of the different categories for each pollutant in the waste sector for the year 2019. Key categories are those shaded.

Table 7.12 *Key categories in the waste sector in 2019*

	5A	**5B1**	**5B2**	**5C1bi**	**5C1biii**	**5C1biv**	**5C1bv**	**5C2**	**5D1**	**5D2**	**5E**
						%					
SO_x				0.03	0.000	0.04	0.01	0.08			
NO_x				0.01	0.002	0.01	0.02	0.30			
NH_3	1.64	0.05	0.76								
NMVOC	0.80	0.04		0.02	0.01	0.001	0.0002	0.24	0.01	0.00	
CO				0.001	0.0001	0.001	0.000	2.13			
PM10	0.00			0.000	0.0002	0.001	0.000	1.40			0.28
PM2.5	0.00			0.00	0.0003	0.000	0.000	1.48			0.35
BC				0.000	0.0001	0.0001		4.81			0.50
Pb				0.00	0.0002	0.01	0.003516	1.15			

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	5A	5B1	5B2	5C1bi	5C1biii	5C1biv	5C1bv	5C2	5D1	5D2	5E
						%					
Cd				0.01	0.0004	0.47	0.02658	11.35			
Hg				0.00	0.01	0.46	0.000				
PAH				0.00	0.000004	0.00	0.000062684	1.83			
Dioxins				0.00	0.003	0.004	0.003	2.70			2.00
HCB				0.05	3.02	1.17	0.00				
PCB				0.01	0.30	0.10	0.00				

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 2019 (Figure 7.1, Figure 7.2, Figure 7.3 and Figure 7.4).

Finally, in Table 7.13, emissions time series for each pollutant of the waste sector are reported. In the period 1990-2019, 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 2019, about 99% of the total amount of waste incinerated is treated in plants with energy recovery system reported in 1A4a.

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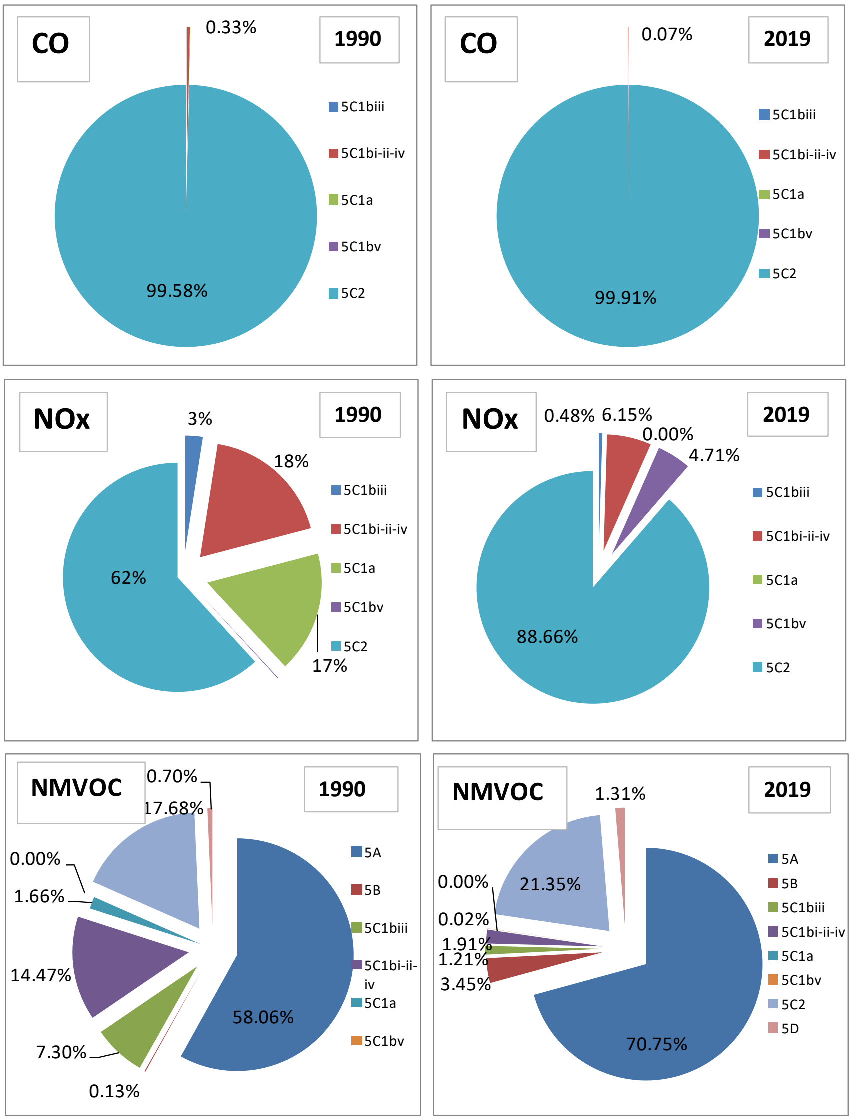

Figure 7.1 *Contribution of CO, NO_X and NMVOC sub-category emissions to waste sector total emissions*

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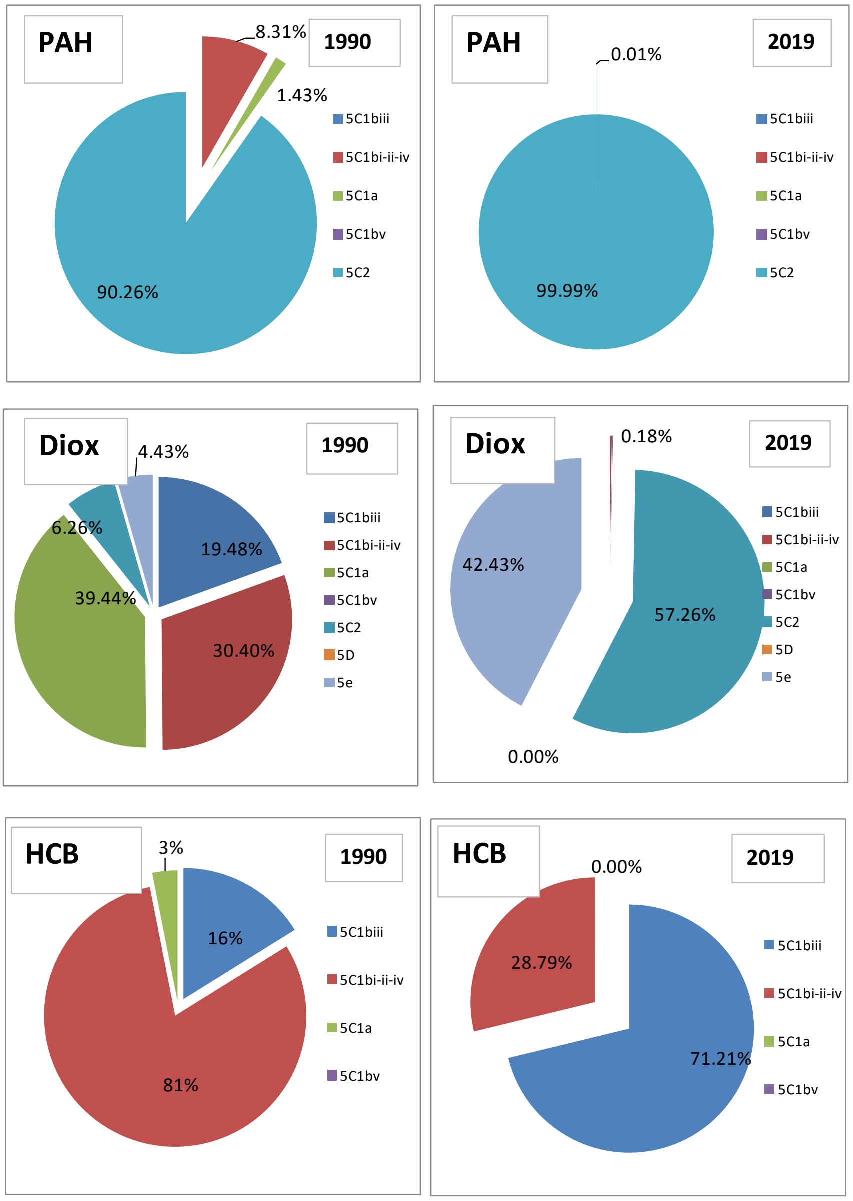

Figure 7.2 *Contribution of POPs Annex III sub-category emissions to waste sector total emissions*

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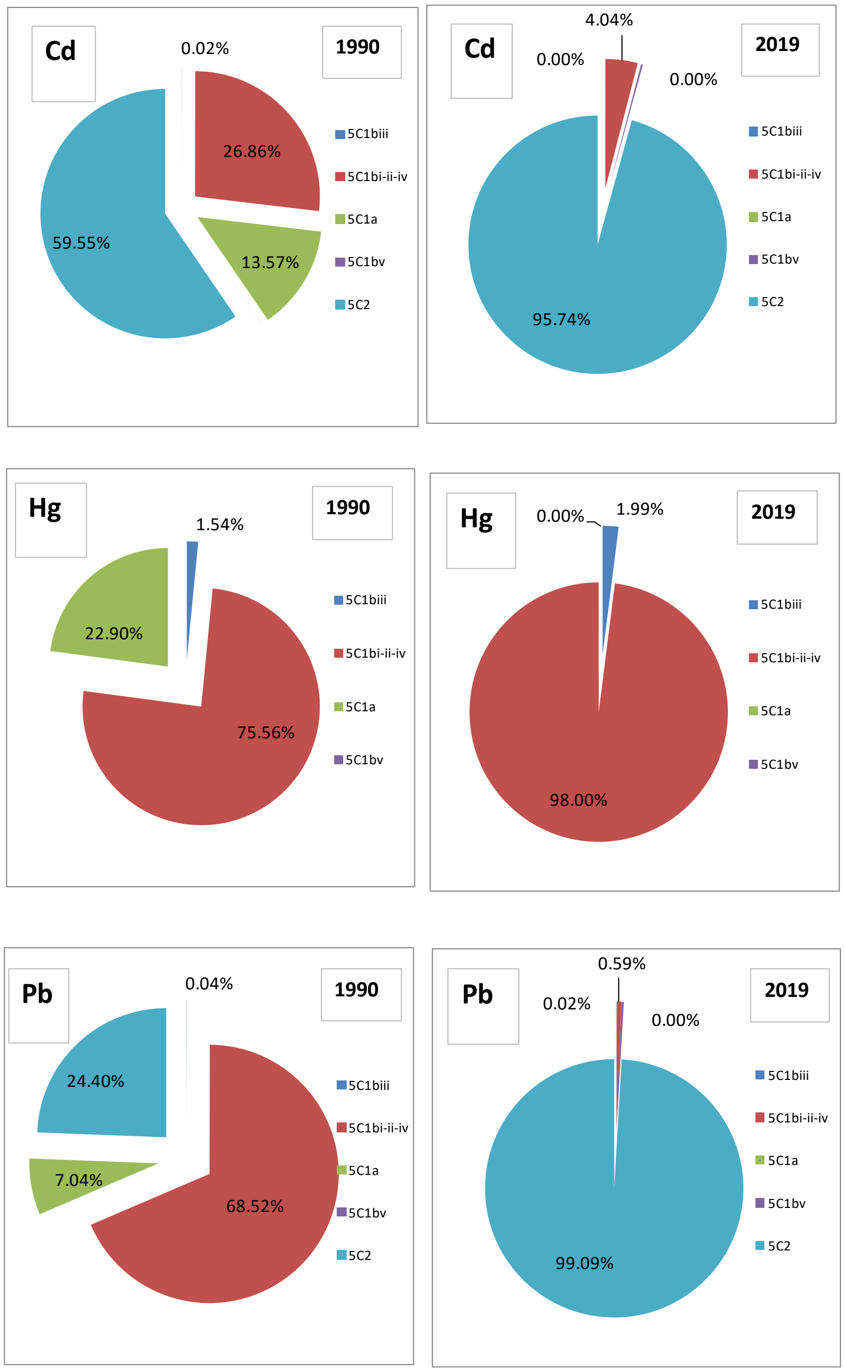

Figure 7.3 *Contribution of priority heavy metals sub-category emissions to waste sector total emissions*

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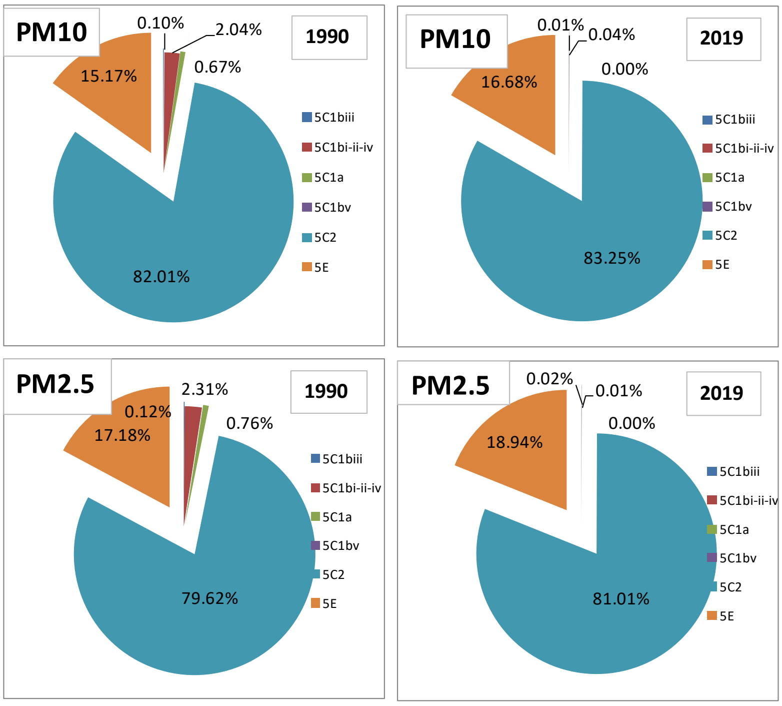

Figure 7.4 *Contribution of PM10 and PM2.5 sub-category emissions to waste sector total emissions*

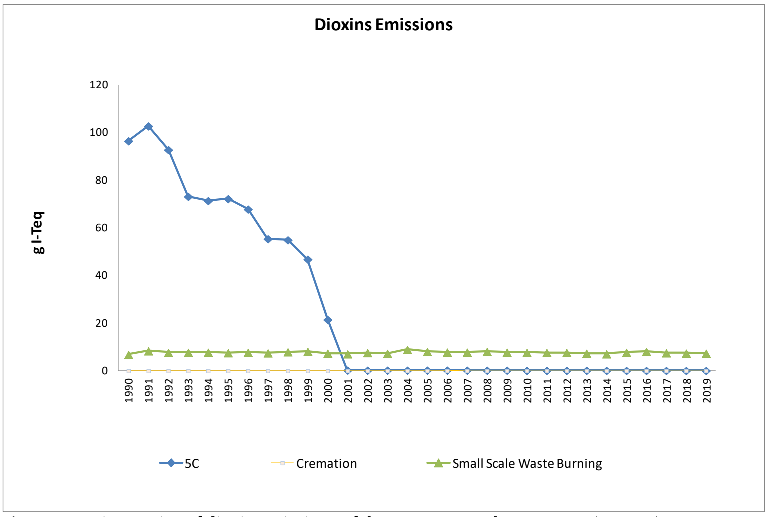

Figure 7.5 *Time series of dioxin emissions of the waste sector by category (g I-Teq)*

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Table 7.13 *Time series emissions in the waste sector by category and pollutant*

WASTE SECTOR	1990	1995	2000	2005	2010	2015	2016	2017	2018	2019
Solid waste disposal (5A)										
NMVOC (Gg)	6.43	7.97	9.06	8.96	8.20	7.38	7.20	7.22	7.25	7.20
NH_3 (Gg)	5.21	6.46	7.35	7.26	6.65	5.99	5.84	5.85	5.88	5.83
PM10 (Gg)	0.004	0.006	0.005	0.004	0.004	0.002	0.002	0.002	0.002	0.002
PM2.5 (Gg)	0.0007	0.0008	0.0008	0.0007	0.0006	0.0004	0.0003	0.0004	0.0003	0.0003
Biological treatment of waste (5B)										
NMVOC (Gg)	0.01	0.03	0.14	0.28	0.36	0.37	0.38	0.37	0.37	0.35
NH_3 (Gg)	0.01	0.06	0.10	0.31	0.46	2.63	2.64	2.69	2.69	2.86
Waste incineration (5C)										
CO (Gg)	40.68	46.90	45.37	50.46	47.17	47.04	48.90	46.01	44.34	43.96
NO_x (Gg)	2.68	2.80	2.35	2.55	2.30	2.21	2.20	2.15	2.07	2.10
NMVOC (Gg)	4.55	4.75	3.26	3.78	3.25	2.90	3.02	2.79	2.49	2.49
SO_x (Gg)	0.55	0.49	0.30	0.34	0.23	0.18	0.15	0.17	0.15	0.17
PM10 (Gg)	2.31	2.54	2.45	2.68	2.53	2.53	2.66	2.47	2.43	2.41
PM2.5 (Gg)	1.99	2.19	2.10	2.31	2.17	2.17	2.28	2.11	2.08	2.07
BC (Gg)	0.81	0.89	0.87	0.95	0.91	0.91	0.96	0.89	0.87	0.87
PAH (t)	1.40	1.45	1.37	1.45	1.21	1.26	1.34	1.21	1.21	1.20
Dioxins (g I-Teq))	103.22	79.68	28.76	8.18	7.73	7.73	8.11	7.52	7.38	7.34
HCB (kg)	12.86	13.96	9.87	8.26	0.48	0.97	0.90	0.82	0.41	0.44
PCB (kg)	5.36	4.61	2.06	1.52	0.53	1.02	0.95	0.86	0.43	0.46
As (t)	0.17	0.21	0.18	0.21	0.17	0.16	0.15	0.16	0.15	0.15
Cd (t)	0.74	0.81	0.69	0.75	0.55	0.57	0.57	0.54	0.53	0.52
Cr (t)	0.68	0.62	0.38	0.43	0.12	0.13	0.12	0.12	0.12	0.12
Cu (t)	1.26	1.31	0.97	0.97	0.54	0.55	0.47	0.51	0.47	0.49
Hg (t)	0.26	0.23	0.12	0.15	0.01	0.03	0.01	0.02	0.02	0.03
Ni (t)	6.76	4.34	2.81	1.02	0.01	0.01	0.01	0.01	0.01	0.02
Pb (t)	7.65	8.09	5.19	6.83	2.76	2.55	2.34	2.43	2.29	2.31
Se (t)	0.10	0.14	0.13	0.15	0.13	0.13	0.12	0.12	0.12	0.12
Zn (t)	40.00	62.50	57.93	67.67	57.68	53.64	46.88	50.69	46.89	47.54
Wastewater (5D)										
NMVOC (Gg)	0.08	0.10	0.10	0.11	0.12	0.11	0.13	0.13	0.13	0.13
Other waste (5E)										
PM2.5 (Gg)	0.41	0.41	0.42	0.42	0.36	0.46	0.50	0.62	0.48	0.48
BC (Gg)	0.08	0.08	0.08	0.08	0.07	0.09	0.09	0.11	0.09	0.09
PCDD/F (g I-Teq)	4.78	4.80	4.85	4.92	4.16	5.21	5.55	6.80	5.41	5.41

7.4 RECALCULATIONS

In the following table the recalculations occurred in the 2021 submission with respect the last year submission are reported at category level.

Table 7.14 *Recalculations in the waste sector by category and pollutant*

WASTE SECTOR	1990	1995	2000	2005	2010	2015	2016	2017	2018
Solid waste disposal (5A)									
NMVOC	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.35%	0.42%	0.48%
NH_3	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.35%	0.42%	0.48%
PM10 (Gg)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%
PM2.5 (Gg)	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%
Biological treatment of waste (5B)									
NMVOC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NH_3	0.00%	14.64%	4.99%	9.79%	12.39%	3.92%	-11.30%	-13.27%	-15.09%
Waste incineration (5C)									
CO	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.77%
NO_x	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%	-0.48%
NMVOC	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.02%	-0.02%	0.05%	-7.97%
SO_x	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	-4.98%

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WASTE SECTOR	1990	1995	2000	2005	2010	2015	2016	2017	2018
PM10	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.80%
PM2.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.79%
BC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.81%
PAH	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.20%
Dioxins	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.61%
HCB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-49.93%
PCB	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-50.27%
As	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.06%	0.75%
Cd	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.55%
Cr	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%	0.46%
Cu	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	-1.73%
Hg	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	7.67%
Ni	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.76%
Pb	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.26%
Se	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	-0.41%
Zn	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%
Wastewater (5D)									
NMVOC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.04%
Other waste (5E)									
PM2.5	0.00%	0.00%	0.00%	0.00%	0.00%	0.53%	-3.61%	-3.73%	-1.37%
BC	0.00%	0.00%	0.00%	0.00%	0.00%	0.53%	-3.61%	-3.73%	-1.37%
PCDD/F (g I-Teq)	0.00%	0.00%	0.00%	0.00%	0.00%	0.47%	-3.29%	-3.46%	-1.25%

Recently, estimates of PM emissions have been included in the inventory for solid waste disposed on landfills. For this category, recalculations occurred because of the update of activity data since 2016 and because of a bug fix in the amount of sludge disposed of in landfills since 2011.

About biological treatment, NH_3 emissions recalculations, as mentioned above, occurred due to the estimates of emissions from anaerobic digestion, in particular changes occurred in the estimate of N from manure management.

As regards incineration, recalculations occur for the update of activity data from 2016. Minor recalculations for COVNM because of a bug fix in emissions from cremation. As concern open burning, the rice production figures for 2017 and 2018 have been updated. Other minor changes were: corrected NMVOC estimation errors for 2016 and 2017, PM2.5 for 2016. Recalculations in the category 5E occurred because of a bug fix in the distribution of buildings categories since 2011.

The analysis regarding incineration plants has been conducted through verifications and comparisons with data reported in E-PRTR registry, Emissions Trading Scheme and updated data of incinerated waste amount by plants.

7.5 PLANNED IMPROVEMENTS

Emissions from 5E are under investigation, the results will be reported in the next submissions. For what concerns cremation of corpses, in 2020 SEFIT, the specific branch of Federutility, which is the federation of energy and water companies which is responsible for crematoria, has carried out together with ISPRA a new survey on emissions from national crematoria. This survey is being finalized and results will be presented soon. Next year we expect to update some emission factors.

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8 RECALCULATIONS AND IMPROVEMENTS

8.1 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 2019 have been submitted. The percentage difference between the time series reported in the 2020 submission and the series reported this year (2021 submission) are shown in Table 8.1 by pollutant.

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 2018 show a decrease for some pollutants and an increase for others; in particular, according to the review process, a significant decrease has been observed for cadmium emissions, equal to 15.0%, mainly due to the update of emission factors for iron and steel activities fuel on the basis of plant specific data, for lead (-4.0%) due to the revision of activity data for fireworks and for PM10 (-1.8%) and PM2.5 (-1.5%) due to the error corrected for cement production and update of activity data for fireworks. The update of COPERT version, due to the update of emission factors of EURO 6 vehicles, and the update of emission factors for cement, lime and glass production, on the basis of EPRTR data, resulted in a recalculation of NO_X (-4.5%). The decrease of NH3 of 2.1% as well as of NMVOC emissions (-1.7%) is driven by different recalculations in the agriculture sector. The decrease of SO_X emissions (-1.2%) is driven by from one side the decrease of emissions due to the update of emission factors for cement, lime and glass production, on the basis of EPRTR data, from the other side by the increase of emissions due to the update of the number of ships arrived in national harbours. The update of COPERT version is responsible for the recalculation of CO emissions (-1.4%). For the other pollutants recalculations for 2018 are less than 1%.

With respect to the base year, according to the review process HCB emissions from use of pesticides have been recalculated resulting in an increase of 107.6%.

In the *energy* sector a further revision of the emission estimates regarded the road transport sector. Specifically, the upgraded version of COPERT model, COPERT 5.4.36 (EMISIA SA, 2020), has been applied to calculate emissions of all pollutants for the whole period 1990-2019, with a revision of emission factors especially for the new vehicles and the introduction of new categories of vehicles. It resulted in a recalculation of the time series for all the pollutants. For 1.A.2 sector a revision of emission factors on the basis of EPRTR plant level data involved Cd and NH_3 emissions for iron and steel sector, SO_X, NO_X, As, Se and Zn emissions for the glass sector, SO_X, NO_X for lime production, SO_X, NO_X, NH_3, CO and PM for cement production. For residential, according to the review process COVNM for 1A4ai and NO_X, COVNM and PM2.5 for 1A4bi have been updated on the basis of the 2019 EMEP/EEA Guidebook emission factors. For 1.A.3.d maritime activities, activity data from 2012 for recreational craft has been updated and estimated on the basis of the trend of the distribution of two and four strokes engines and their average gasoline fuel consumption. For 1.A.3.a category, aviation, there has been an update for the entire time series of the engine classification and for consumption data since 2005 according to data provided by EUROCONTROL for Italy.

In the *industrial processes* sector, recalculations occurred because of the update of PM10 emission factor for cement production according to the recommendation of the review (EEA, 2020). Emissions from use of fireworks have also been updated following the review recommendation (EEA, 2020). Minor recalculations occurred because of the update of activity data for the following source categories: chipboard, bread, beer, spirits, glass, tobacco, steel and chemical products**.**

For the *solvent* sector minor recalculations occurred because of the update of activity data in the manufacture of automobiles, fat edible, aerosol cans and cosmetics in domestic solvent use.

In 2020, recalculations were implemented for the *agricultural* emission inventory. As result from the 2020 NEC review, the HCB emissions from the use of pesticides have been revised for the whole time series. The update of GE estimate of dairy cows from 2014, related to methane emissions from enteric fermentation, resulted in a change in excreted nitrogen from dairy cows, which changes NH_3, NO_2 and NMVOC emissions

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from manure management and soils. Updated data on N excreted for turkeys since 2007. As recommends during the 2020 NECD review (EEA, 2020), NMVOC and PM estimation for turkeys, previously included in the category other poultry, carried out. Minor recalculations occurred for the update of activity data.

As regards the *waste* sector, recalculations occur for the category 5C, because of the update of activity data for industrial waste incineration resulting in a huge decrease of HCB and PCB emissions in 2018. About biological treatment, in particular emissions from anaerobic digestion, NH_3 emissions recalculations occurred due to changes occurred in the estimate of N from manure management.

Table 8.1 *Recalculation between 2020 and 2021 submissions*

	SO_X	NO_X	NH_3	NMVOC	CO	PM10	PM2.5	BC	Pb	Hg	Cd	DIOX	PAH	HCB	PCB
								%							
1990	-0.00	0.06	-0.11	1.46	-0.01	-1.14	-0.61	1.15	-0.20	-0.00	-0.00	-1.02	-0.01	108.76	-0.00
1991	-0.00	0.05	-0.17	1.60	-0.00	-1.10	-0.61	1.16	-0.27	-0.00	0.02	-0.88	-0.01	106.64	-0.00
1992	-0.00	0.04	-0.19	1.81	0.00	-1.03	-0.51	1.30	-0.35	-0.00	0.05	-0.87	-0.01	105.62	-0.00
1993	-0.00	0.06	-0.20	1.84	-0.00	-0.80	-0.34	1.31	-0.39	-0.00	0.05	-0.97	-0.01	102.88	-0.00
1994	-0.06	0.07	-0.22	1.83	-0.00	-0.78	-0.34	1.35	-0.44	-0.00	0.05	-0.91	-0.01	101.32	-0.00
1995	-0.03	0.08	-0.21	1.81	-0.00	-0.64	-0.24	1.40	-0.46	-0.00	0.04	-0.76	-0.01	95.08	-0.00
1996	-0.03	0.06	-0.21	1.87	-0.00	-0.75	-0.51	1.34	-0.40	-0.00	0.08	-0.73	-0.01	39.16	-0.00
1997	-0.00	0.08	-0.24	1.89	-0.01	-0.80	-0.36	1.44	-0.47	-0.00	0.06	-0.62	-0.01	77.36	-0.00
1998	-0.01	0.13	-0.21	2.25	0.05	-0.91	-0.53	1.31	-0.53	-0.00	0.08	-0.66	-0.01	162.84	-0.00
1999	-0.01	0.17	-0.21	2.43	0.08	-0.78	-0.43	1.34	-0.41	-0.00	0.15	-0.60	-0.01	80.70	-0.00
2000	0.07	-0.06	-1.01	1.85	0.05	-1.37	-1.05	1.11	-0.31	-0.00	0.18	-0.58	-0.02	-5.82	0.00
2001	0.07	-0.01	-0.71	1.80	-0.05	-1.30	-1.18	0.98	-0.40	-0.01	0.19	-0.44	-0.02	-8.83	0.00
2002	0.08	-0.01	-0.91	1.53	-0.26	-1.89	-1.44	1.11	-1.03	-0.01	0.22	-0.38	-0.02	-0.34	0.00
2003	0.30	0.10	-0.93	1.25	-0.46	-1.83	-1.32	1.02	-1.14	-0.02	-6.37	-0.19	-0.02	-2.73	0.00
2004	0.33	0.10	-1.34	0.61	-0.81	-0.50	0.08	1.33	-0.94	-0.10	-8.15	-0.03	-0.13	-6.47	0.00
2005	0.44	-0.17	-1.58	-1.51	-0.76	-2.07	-1.57	1.35	-0.32	-0.02	-8.64	0.05	0.00	-9.13	0.00
2006	0.41	0.16	-1.68	-1.44	-0.81	-2.17	-1.65	0.86	-0.58	-0.02	-11.34	0.19	0.01	-13.36	0.00
2007	0.87	0.14	-1.73	-1.37	-0.87	-1.56	-1.21	0.91	0.06	-0.02	-8.40	0.19	0.00	-6.18	0.00
2008	1.32	-0.31	-1.70	-1.38	-0.93	-1.35	-1.02	0.97	-0.60	-0.08	-14.40	0.19	-0.00	-14.18	0.00
2009	1.70	-0.17	-1.72	-1.45	-1.12	-1.62	-1.18	1.13	-2.25	-0.16	-6.46	0.26	-0.01	-29.46	0.00
2010	1.61	-1.09	-2.57	-1.76	-1.31	-1.49	-1.12	0.89	-1.41	-0.19	-14.98	0.34	0.03	-40.99	0.00
2011	1.79	-0.47	-2.82	-1.76	-1.54	-1.46	-1.01	1.60	-1.23	-0.18	-18.40	0.27	-0.01	-42.37	0.00
2012	1.44	-0.70	-2.75	-0.57	-0.82	-1.00	-0.61	1.59	-1.71	-0.17	-21.64	0.24	-0.01	-38.48	-0.00
2013	2.01	-1.00	-3.38	-0.91	-0.99	-1.11	-0.73	1.86	-3.17	-0.18	-19.65	0.21	-0.01	5.44	-0.00
2014	1.06	-1.40	-3.65	-1.32	-1.26	-1.21	-0.81	2.38	-3.16	-0.14	-20.42	0.24	-0.01	5.28	-0.00
2015	1.95	-1.83	-3.83	-1.78	-1.43	-1.41	-0.99	2.37	-3.72	-0.18	-16.62	0.24	-0.01	5.24	-0.00
2016	2.10	-1.78	-2.38	-1.84	-1.49	-1.61	-1.09	2.24	-4.32	-0.17	-18.08	0.20	-0.01	5.99	-0.00
2017	1.47	-3.86	-2.27	-2.37	-3.09	-1.50	-1.12	1.14	-3.67	-0.04	-16.00	0.13	-0.05	5.87	-0.00
2018	-1.24	-4.50	-2.12	-1.74	-1.41	-1.78	-1.31	0.45	-4.12	-0.01	-15.02	0.14	0.04	0.93	0.15

8.2 PLANNED IMPROVEMENTS

Specific improvements are specified in the QA/QC plan (ISPRA, 2021[b]); they can be summarized as follows.

For the *energy* and *industrial processes* sectors, a major progress regards the harmonisation 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 and for POPs emissions the use of the results of a national research in the potential update of emission factors and methodologies in the iron and steel sector. 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

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in agriculture practices and the elaboration of data from the 2016 farm structure survey and availability of information on the landfill gas combustion in landfills flaring and emissions from the exceeding biogas flared at wastewater treatment plants are under investigation.

The EMEP/EEA Guidebook 2019 chapters (EMEP/EEA, 2019) has started to be considered, and update emission factors will be applied in the next year submission of the inventory with a focus to PAH, dioxin and heavy metals 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.

The update of the energy chapter of the IIR is planned to increase the transparency on methodologies and emission factors used for 1A1 and 1A2 categories.

Further analyses will concern the collection of statistical data and information to estimate uncertainty in specific sectors.

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9 PROJECTIONS

The emission scenarios have become increasingly important in the definition of international, European and national policies on atmospheric pollution. The European Commission, for example, in the elaboration of the Clean Air Policy Package (COM, 2013) with the aim to further reduce the impacts of harmful emissions on human health and the environment, asked IIASA (International Institute for Applied Systems Analysis) to elaborate emission scenarios with the integrated assessment model GAINS-Europe (Greenhouse Gas and Air Pollution Interactions and Synergies Model, Amann et al., 2011) to explore the potential for environmental improvements.

Italy too has its own integrated air quality assessment model, the MINNI model (National Integrated Model to support the International Negotiation on atmospheric pollution, Mircea et al., 2014, 2016, 2019) an ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) project where the GAINS-Italy model (Greenhouse Gas and Air Pollution Interactions and Synergies Model over Italy, D'Elia et al., 2018; Ciucci et al., 2016, D'Elia et al., 2009), run by ENEA and developed in collaboration with IIASA, elaborates the emission scenario at national and regional level.

9.1 THE NATIONAL FRAMEWORK

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 new European Directive on National Emission Ceilings, 2016/2284/EC (EC, 2016), 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) and the national GAINS-Italy. They interact in a feedback system through ATMs (*Atmospheric Transfer Matrices*) and RAIL (*RAINS-Atmospheric Inventory link*).

The GAINS-Italy model (fig. 9.1) 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 NO_2 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).

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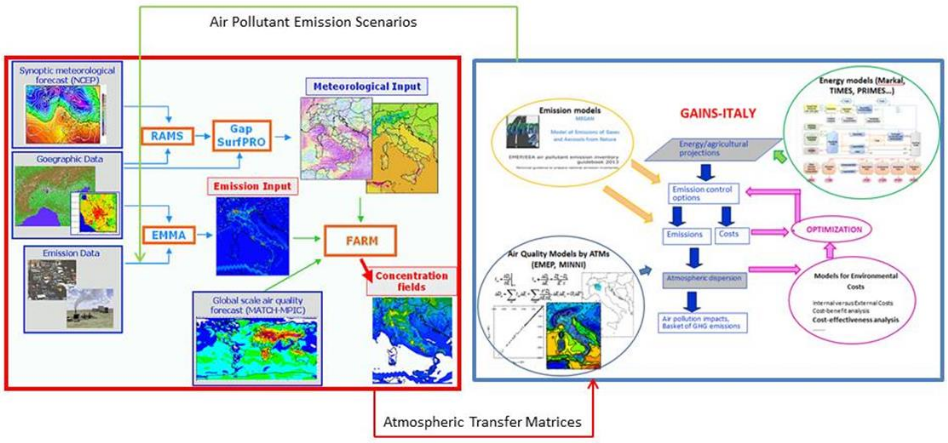

Figure 9.1 – *The simplified functional flow-chart of the MINNI national modelling scheme.*

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. In the present chapter, the scenarios that will be discussed are the are the Baseline scenario (with measures, WM_NECP) and the Policy scenario (with additional measures, WAM_NECP) elaborated for the National Energy and Climate Plan (NECP, https://ec.europa.eu/energy/sites/ener/files/documents/it_final_necp_main_en.pdf).

9.2 INPUT SCENARIOS

9.2.1 The energy scenario

The Energy scenario used as input to the GAINS-Italy model has been produced by ISPRA with the TIMES (The Integrated MARKAL-EFOM1 System / EFOM Energy Flow Optimization Model, Loulou et al., 2004; Loulou et al., 2005) model developed as part of the IEA-ETSAP (Energy Technology Systems Analysis Program). TIMES is a technology rich, bottom-up model generator, which uses linear-programming to produce a least-cost energy system, optimized according to a number of user constraints, over medium to long-term time horizons.

The model has been developed considering the detailed energy input needed by GAINS-Italy so that the two models are fully integrated and all the information needed by GAINS-Italy can be found in the TIMES output, that describes, for each sector, the amount of energy carriers, raw materials used, and goods or services produced.

In 2020 the National Energy and Climate Plan (NECP) has been submitted to the European Commission, the scenarios used as input to the GAINS model are consistent with the scenarios included in the NECP. Scenario are also consistent with those submitted to the EU Commission under regulation 525/2013 and available at http://cdr.eionet.europa.eu/it/eu/mmr/art04-13-14_lcds_pams_projections/envvxfh1a/

9.2.2 The scenario of non-energy activities

To develop an emission scenario, the GAINS-Italy model requires the definition also of non-energy activities level. The definition of such scenario is based on economic variables, like GDP (gross domestic product) or added value derived from the energy scenario, population data or specific sector statistics.

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Livestock projection has been carried out with a statistical model where the number of animals has been linked to the projections of other variables, like meat consumption and production, or milk consumption and production (see equation 9.1)

$$(n°heads_i) = \left(\frac{n°heads_i}{MP_i}\right) \times \left(\frac{MP_i}{MC_i}\right) \times \left(\frac{MC_i}{MC_{tot}}\right) \times \left(\frac{MC_{tot}}{Pop}\right) \times (Pop) \quad (9.1)$$

where the head number of livestock *i* is linked to meat production (*MP*) and consumption (*MC*) of livestock *i*, total meat consumption (MC_{tot}) and population (*Pop*).
All the details about this methodology are provided in D'Elia and Peschi, 2013.

The updated livestock projections have been elaborated for the baseline WM_NECP: population data (*Pop*) are the same of the NECP energy scenario, while for meat production and consumption sectorial studies and statistics have been considered (http://www.ismeamercati.it/carni).

In the following figures, the results for the main livestock are reported where

- ISPRA stands for the activity data considered in the 2020 emission submission, that was the last submission available when the livestock projections were elaborated;
- WM_NECP are the new projections elaborated for the WM_NECP scenario.

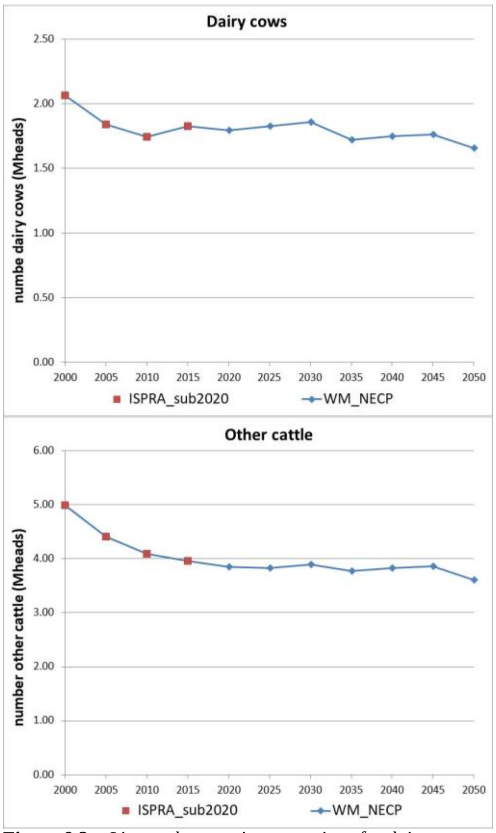

Figure 9.2 – *Livestock scenario comparison for dairy cows and other cattle.*

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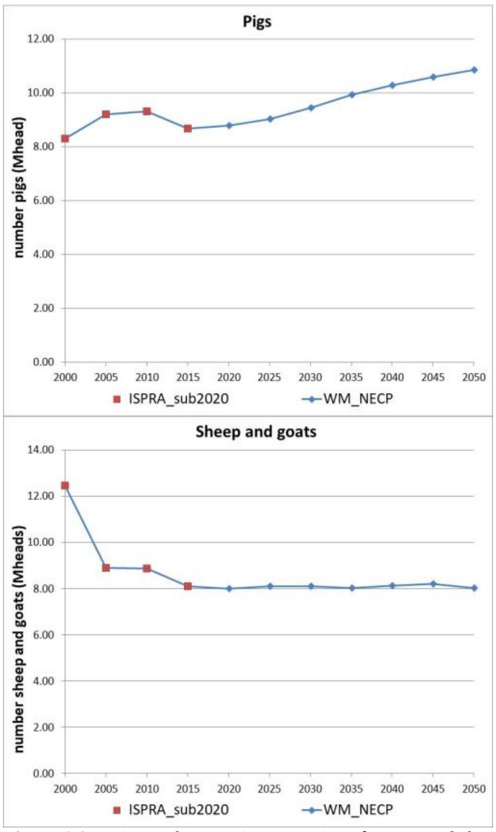

Figure 9.3 – *Livestock scenario comparison for pigs and sheep and goats.*

9.2.3 The control strategy definition

In addition to energy, climate and agricultural policies assumed in the energy, non energy and agricultural input scenarios, in the baseline emission projections a detailed inventory of national emission control legislation is considered (Amann et al., 2011).

In the WM_NECP scenario it is assumed that all the European and national regulations adopted before 2020 will be fully complied according to the foreseen time schedule. Examples of the legislations considered are the Directive on Industrial Emissions for large combustion plants, the Directives on Euro standards, Solvent Directive, the Code of Agricultural Good Practice.

In the WAM_NECP it is assumed that all the policies and targets set out in the NECP will be adopted.

An example of the WM_NECP control strategy for the road transport sector is reported in the following figures.

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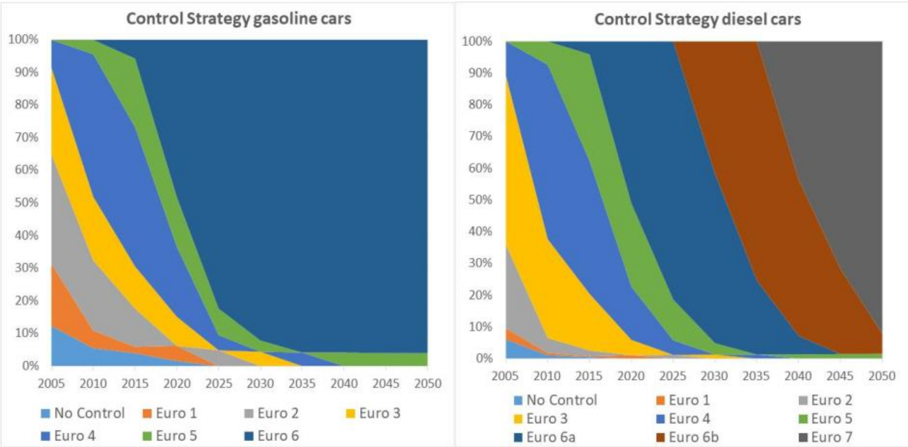

Figure 9.5 – *Control strategy for gasoline (on the left) and diesel (on the right) cars.*

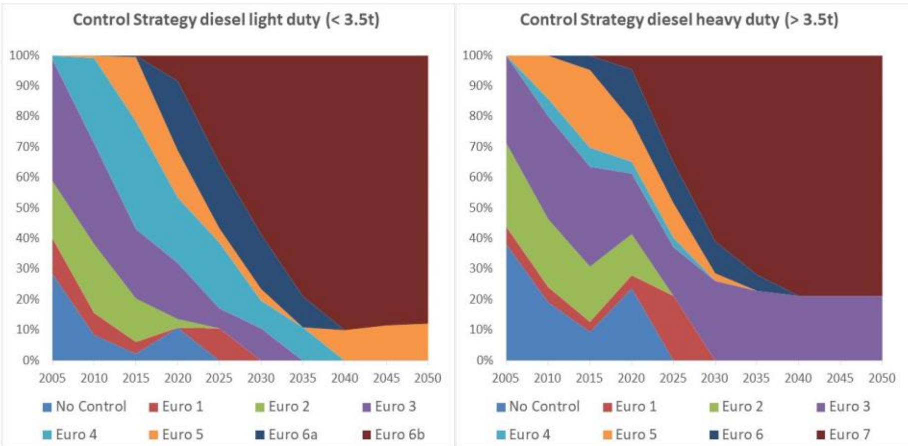

Figure 9.6 – *Control strategy for diesel light (on the left) and heavy (on the right) duty vehicles.*

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9.3 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, (https://www.ceip.at/ms/ceip_home1/ceip_home/status_reporting/2020_submissions/) and the GAINS-Italy emission estimates has been carried out considering three historical years, 2005, 2010 and 2015. Results of the harmonization process between the 2020 emission inventory submission (INVENTORY_sub2020) and GAINS-IT estimates are summarized in Table 9.1.

Table 9.1 –Comparison of total emissions in the last submission of the national inventory report (INVENTORY_sub2020) and GAINS-Italy estimates (GAINS-IT), for the years 2005, 2010 and 2015.

	Emissions 2005			Emissions 2010			Emissions 2015		
Pollutant	INVENTORY _sub2020 (kt)	GAINS-IT (kt)	□□ (%)	INVENTORY _sub2020 (kt)	GAINS-IT (kt)	□ (%)	INVENTORY _sub2020 (kt)	GAINS-IT (kt)	□ (%)
SO_2	409	393	-3.87%	218	209	-4.25%	124	120	-3.22%
NO_X	1291	1231	-4.70%	945	985	4.23%	732	744	1.62%
PM2.5	176	176	-0.09%	198	196	-1.34%	159	166	4.42%
NMVOC	1361	1232	-9.47%	1137	993	-12.68%	917	800	-12.74%
NH_3	426	412	-3.22%	387	384	-0.86%	379	381	0.52%

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Discrepancies in reproducing the national emission inventory have been considered acceptable if differences remain within a few percentage points, i.e. in the interval between ± 5%. The higher differences in NMVOC emissions for all the three years depend on the estimates of emissions from the agricultural sector (NFR code 3) that in the model estimates have not yet been considered but they will be introduced in the emission projection update that is underway.
In the following plots, details on sectoral emissions by NFR code (Nomenclature For Reporting; Table 9.2 reports the sectors considered) are illustrated for the year 2015.

Table 9.2 – Definition of the NFR code used in the comparison between emission inventory and GAINS-IT estimates.

NFR code	Description
1A1	Energy industries (Combustion in power plants & Energy Production)
1A2	Manufacturing Industries and Construction (Combustion in industry including Mobile)
1A3b	Road and Off-road Transport
1A4	Other sectors (Commercial, institutional, residential, agriculture and fishing stationary and mobile combustion)
1A5	Other
1B	Fugitive emissions (Fugitive emissions from fuels)
2	Industrial Processes and Solvent use
3	Agriculture
5	Waste
6A	Other (included in National Total for Entire Territory)

For SO_2 emissions, the model shows a slight overestimate of the sector 1A1 and 2, an underestimate of the sectors 1A2, and 1A4, while for NO_X there is a slight overestimate of the sector 1A3. Emissions from the agriculture sector (code 3) both for NO_X and NMVOC are missing in GAINS-IT and will be added in future updates.
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 reported in 1A4 and 2 sectors.
The model shows a slight overestimate in NMVOC emissions from the sector 2 – Industrial process and solvent use and in NH_3 emissions from the sector 3 – Agriculture in the range of uncertainty considered acceptable.

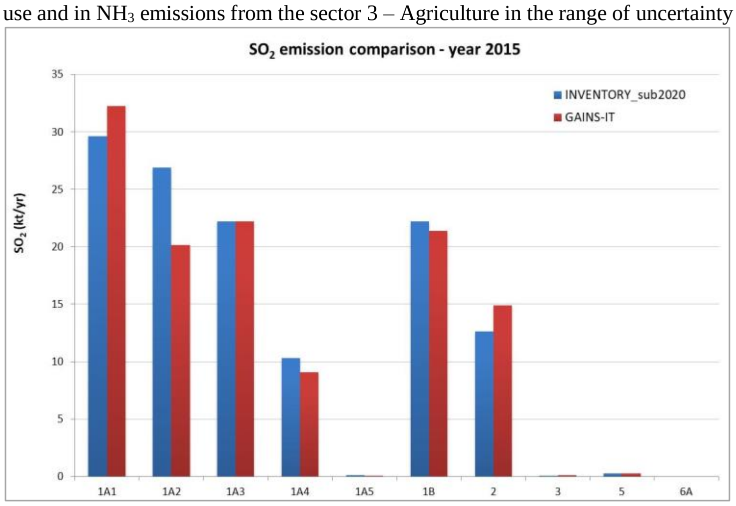

Figure 9.6 – *SO_2 national emission harmonization between the last emission inventory (INVENTORY_sub2020) and GAINS-IT estimates detailed by NFR sectors for the year 2015.*

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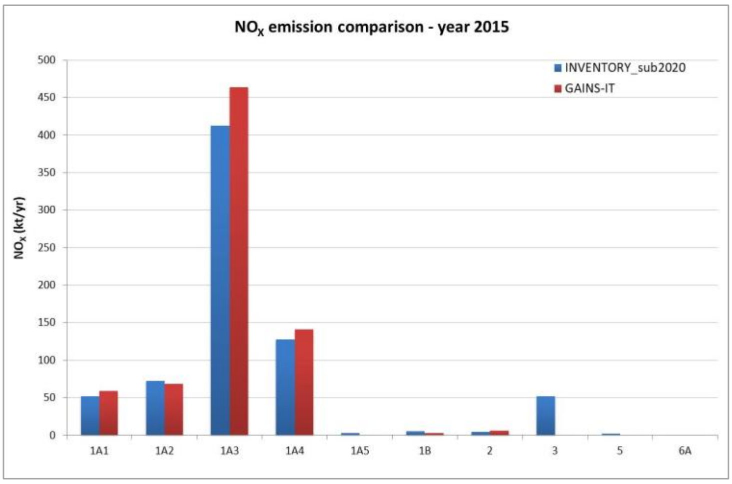

Figure 9.7 – *NO_X national emission harmonization between the last emission inventory (INVENTORY_sub2020) and GAINS-IT estimates detailed by NFR sectors for the year 2015.*

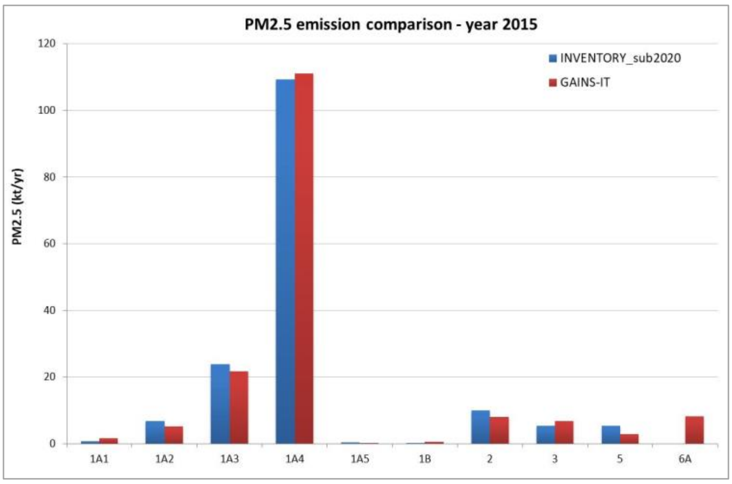

Figure 9.8 – PM2.5 *national emission harmonization between the last emission inventory (INVENTORY_sub2020) and GAINS-IT estimates detailed by NFR sectors for the year 2015.*

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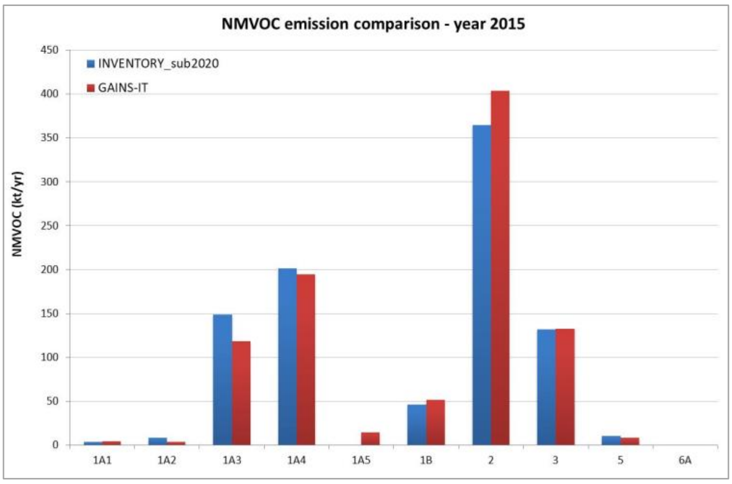

Figure 9.9 – NMVOC *national emission harmonization between the last emission inventory (INVENTORY_sub2020) and GAINS-IT estimates detailed by NFR sectors for the year 2015.*

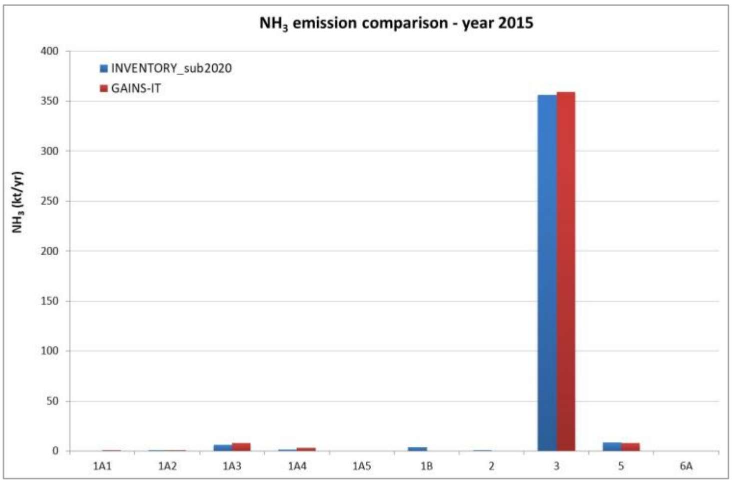

Figure 9.10 – NH_3 *national emission harmonization between the last emission inventory (INVENTORY_sub2020) and GAINS-IT estimates detailed by NFR sectors for the year 2015.*

9.4 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 2020 emission inventory submissions, the WM_NECP and WAM_NECP scenarios, used for NECP, are presented. Details by NFR sector are presented for the WAM_NECP; the WM_NECP scenario description was discussed in the previous IIR (IIR, 2020).
A huge decrease in SO_2 emissions is projected (fig. 9.11) driven by the energy and the maritime sector for the year 2020 and 2030 while the industrial sector (1A2) represents the main emitting sector (fig. 9.12).

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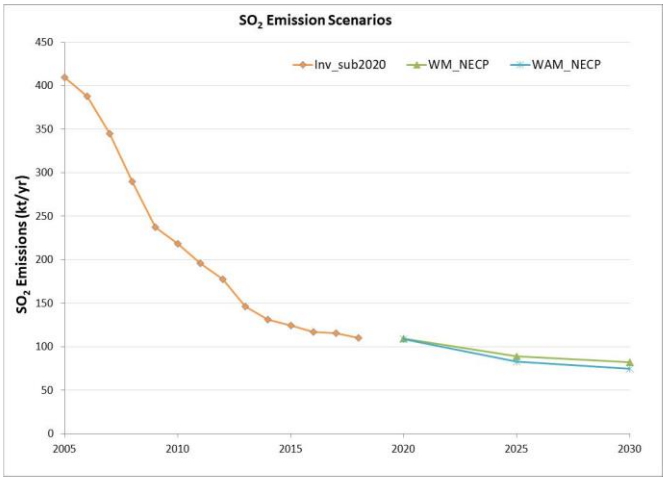

Figure 9.11 *–Reported and projected (WM_NECP, WAM_NECP) SO_2 emissions elaborated by the GAINS-Italy model.*

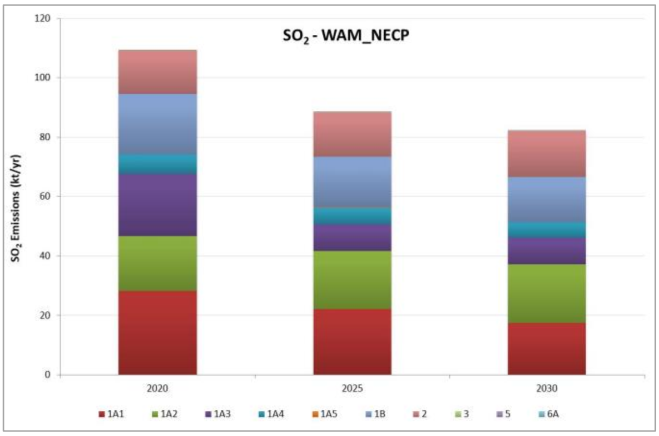

Figure 9.12 *–SO_2 emissions by NFR sectors in the WAM_NECP scenario.*

A huge decrease is estimated in NO_X emission scenarios (fig. 9.13) due to the diffusion of new diesel Euro 6 vehicles and electric vehicles. The road transport sector still represents the principle NO_X source (fig. 9.14).

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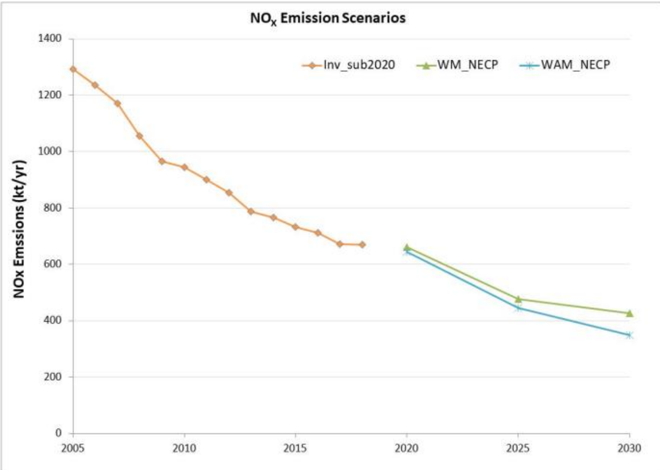

Figure 9.13 –*Reported and projected (WM_NECP, WAM_NECP) NO_X emissions elaborated by the GAINS-Italy model.*

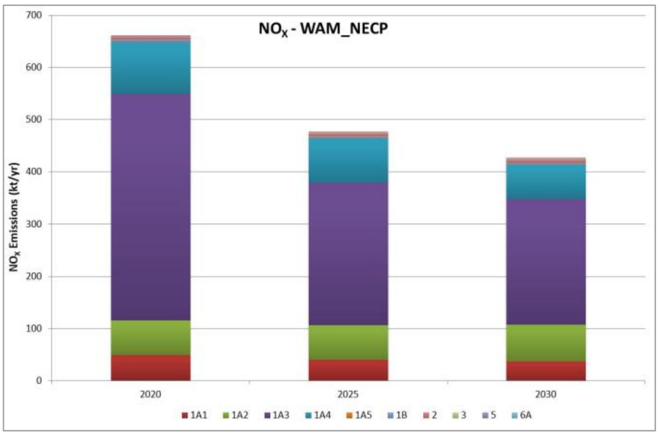

Figure 9.14 – *NO_X emissions by NFR sectors in the WAM_NECP scenario.*

The decrease of the PM2.5 WAM_NECP scenario (fig. 9.15) is driven by the civil sector (1A4) that continues to represent the main emitting sector (fig. 9.16).

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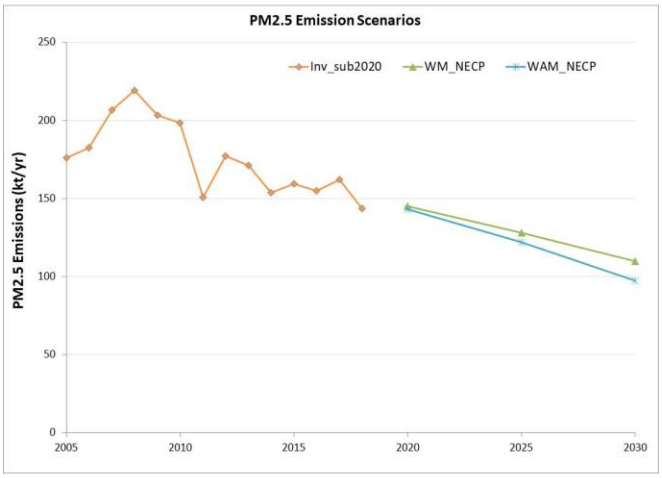

Figure 9.15 *–Reported and projected (WM_NECP, WAM_NECP) PM2.5 emissions elaborated by the GAINS-Italy model.*

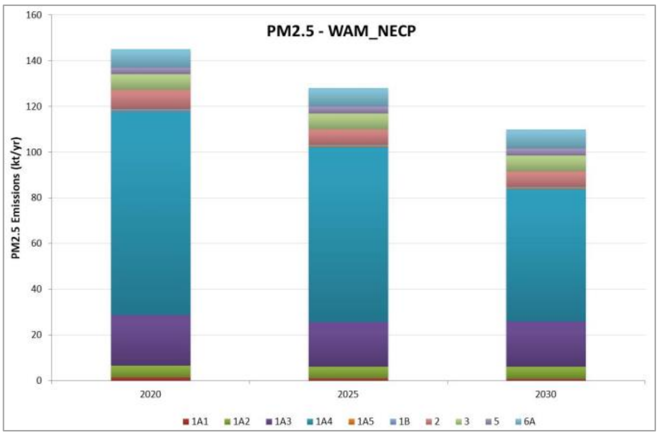

Figure 9.16 – *PM2.5 emissions by NFR sectors in the WAM_NECP scenario.*

As already underlined, the gap between the reported and projected NMVOC emissions (fig. 9.17) is due to the estimate of the sectors 3B and 3D, that will be solved in future submissions. The solvent sector will remain the main emitting sector (fig. 9.18).

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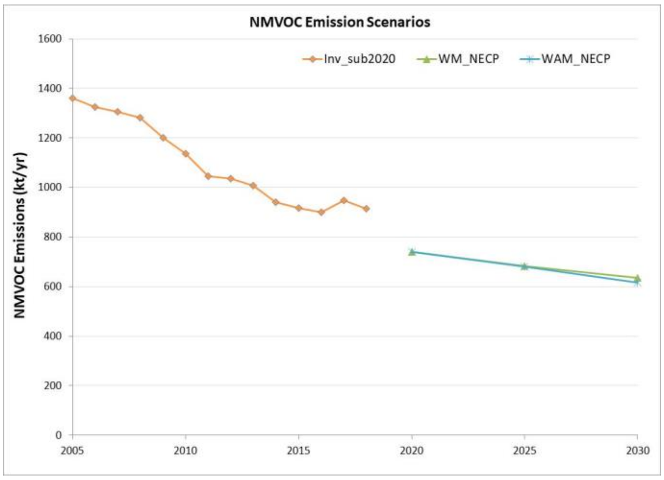

Figure 9.17 –*Reported and projected (WM_NECP, WAM_NECP) NMVOC emissions elaborated by the GAINS-Italy model.*

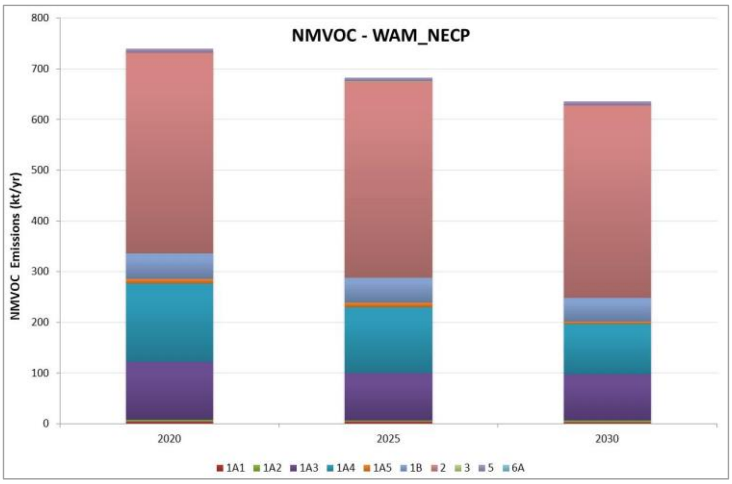

Figure 9.18 – *NMVOC emissions by NFR sectors in the WAM_NECP scenario.*

NH_3 is the pollutant with less variations (fig. 9.19) whose main contribution to total NH_3 emissions is due by the agricultural sector (fig. 9.21).

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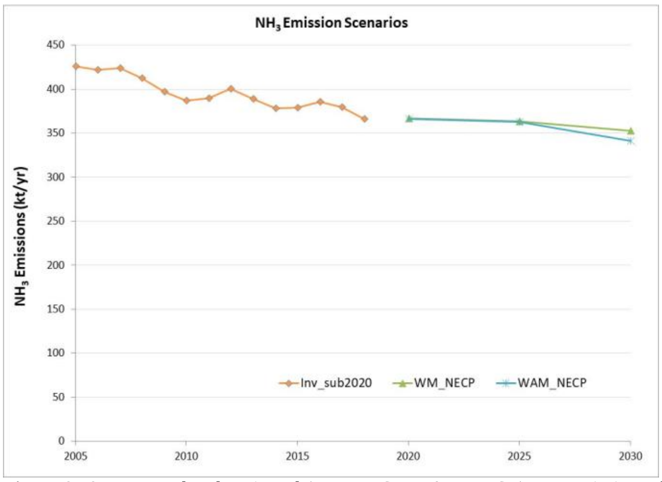

Figure 9.19 –*Reported and projected (WM_NECP, WAM_NECP) NH_3 emissions elaborated by the GAINS-Italy model.*

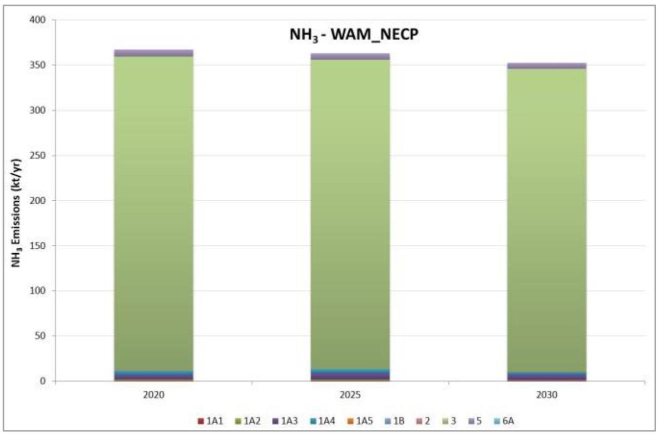

Figure 9.20 – *NH_3 emissions by NFR sectors in the WAM_NECP scenario.*

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9.5 THE NEC EMISSION TARGETS

The new NEC Directive (EC, 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, NO_X, PM2.5, NMVOC and NH_3.
In Tables 9.3 and 9.4 the attainment of the national emission reductions in the years 2020 and 2030, respectively, in the comparison with the new National Emission Ceilings Directive (NECD) targets is reported.

Table 9.3 – National emission reductions in the year 2020 respect to the base year 2005 and comparison with the new National Emission Ceilings Directive (NECD) targets.

	2020 EMISSION REDUCTIONS		
	NECD targets	WM_NECP	WAM_NECP
SO_2	-35%	-72%	-72%
NO_X	-40%	-46%	-48%
PM2.5	-10%	-18%	-19%
NMVOC	-35%	-40%	-40%
NH_3	-5%	-11%	-11%

Table 9.4 – National emission reductions in the year 2030 respect to the base year 2005 and comparison with the new National Emission Ceilings Directive (NECD) targets.

	2030 EMISSION REDUCTIONS		
	NECD targets	WM_NECP	WAM_NECP
SO_2	-71%	-79%	-81%
NO_X	-65%	-65%	-72%
PM2.5	-40%	-37%	-45%
NMVOC	-46%	-48%	-50%
NH_3	-16%	-14%	-17%

According to the present emission projections, all the targets should be met in 2020 already in the WM_NECP scenario, while for the 2030 targets additional measures have been adopted. The WAM_NECP scenario respects the NO_X, PM2.5, NMVOC and NH_3 targets.

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10 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).

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 10.1. Proxy used for disaggregation have been reported too.

Table 10.1 Aggregation for Gridding and LPS of NFR sector

NFR Aggregation for Gridding and LPS (GNFR)	Proxy
A_PublicPower	point sources consumptions from ETS/LPS
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
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

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	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	
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.

10.1 FUGITIVE

Proxy used for disaggregation of 1B1 and 1B2 are reported in the Table 10.2.

Tab. 10.2 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

10.2 TRANSPORT

Proxy used for disaggregation of the different transport mode are reported in the Table 10.3.

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Tab. 10.3 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.

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10.3 AGRICULTURE

Proxy used for disaggregation of the agriculture sector are reported in the Table 10.4.

Tab. 10.4 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)
3Da2, 3Da3, 3De	For NH_3 emissions from livestock, provincial emissions were estimated by multiplying the number of heads for each animal category available at provincial level (ISTAT) by the provincial emission factors by animal category. For N_2O and NOx emissions from spreading and grazing, the proxies used are the provincial distributions of nitrogen excreted at the housing and grazing separately.
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	For NH_3 emissions, provincial emissions were estimated by multiplying the number of heads for each animal category available at provincial level (ISTAT) by the provincial emission factors by animal category from a 1994 study (Research Centre on Animal Production - CRPA). These provincial emissions for each animal category are the sum of emissions from all stages of manure management (i.e. housing, storage, spreading and grazing). National emissions for each animal category (which is the sum of emissions from all stages of manure management) were then disaggregated on the basis of these provincial emissions. For each animal category, the emission factors for each stage of manure management are considered. The percentage weight of the emission factors for each stage of manure management is calculated for each animal category. These percentages apply to the provincial total NH3 emissions of all the stages, to calculate the provincial emissions (overall of all the animal categories) for the different stages distinctly. Finally, on the basis of these provincial emissions, the national emissions of each stages of manure management are disaggregated, separately. For CH_4 emissions, 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. For NMVOC, national emissions were disaggregated on the basis of CH_4 provincial emissions. For NOx and PM emissions, national emissions were disaggregated on the basis of the number of heads available at provincial level (ISTAT)
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)

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10.4 LPS DATA

LPS data for the year 2015 have been submitted in 2017. A brief description of data is reported in the following Table 10.5.

Table 10.5 Characterization of LPS data

GNFR	n° plant	Height class/n°
A_PublicPower	51	1/18; 2/15; 3/5; 4/4; 5/9
B_Industry	162	1/109; 2/39; 3/11; 4/2; 5/1
C_OtherStationaryComb	1	1/1
D_Fugitive	1	1/1
E_Solvents	39	1/39
J_Waste	10	1/2; 2/4; 3/4
K_AgriLivestock	874	1/874

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. Data about HCB and PM2.5 emissions have been verified and the consistency between E-PRTR and LPS data for agricultural facilities has been checked. All these checks and verification have been taken into consideration in the realization of the new dataset will constitute the 2021 submission

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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 figureA6.1).

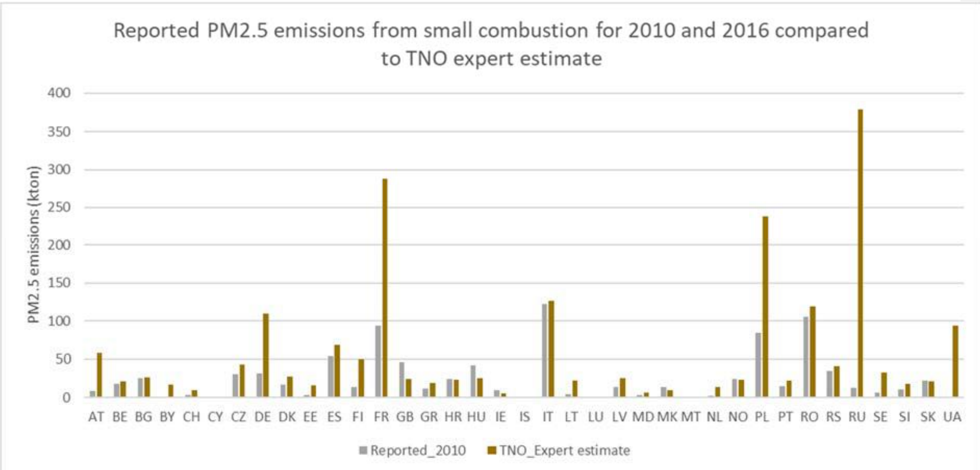

Figure A6.1 Comparison between TNO and countries estimates

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