ISPRA
Istituto Superiore per la Protezione
e la Ricerca Ambientale

RAPPORTI

Italian Emission Inventory 1990 - 2015

Informative Inventory Report 2017

262/2017

ISPRA
Istituto Superiore per la Protezione
e la Ricerca Ambientale

Italian Emission Inventory 1990 - 2015

Informative Inventory Report 2017

Rapporti 262/2017

ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale
Via Vitaliano Brancati, 48 – 00144 Roma
www.isprambiente.it

ISPRA, Rapporti 262/2017

ISBN 978-88-448-0823-5

Graphic design:
ISPRA
Cover design: Alessia Marinelli
Cover drawing: Chiara Arcarese

Typographic coordination:
Daria Mazzella
ISPRA – Communications Area

Text available on ISPRA website at http://www.isprambiente.gov.it

Authors
Ernesto Taurino, Antonella Bernetti, Riccardo De Lauretis, Ilaria D'Elia (ENEA), Eleonora Di Cristofaro, Andrea Gagna, Barbara Gonella, Francesca Lena, Monica Pantaleoni, Emanuele Peschi, Daniela Romano, Marina Vitullo

Contact: Riccardo De Lauretis
telephone +39 0650072543
e-mail riccardo.delauretis@isprambiente.it

ISPRA- Institute for Environmental Protection and Research
Environmental Assessment, Control and Sustainability Department
Emissions, Prevention of Atmospheric Impacts and Climate Change Area
Air Emission Inventory Unit
Via V. Brancati, 48 00144 Rome ITALY

CONTENTS

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 2015, 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 1990-2015, emissions from almost all the pollutants described in this report show a downward trend. Reductions are especially relevant for the main pollutants (SO_X -93%; NO_X -62%; CO -67%; NMVOC -56%) and lead (-94%). 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 90%; NO_X 96%; CO 95%; PM2.5 91%; PM10 85%; BC 95%; Cd 83%, PAH 82%). 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; 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 96% in national total. Finally, the waste sector, specifically waste incineration, is a relevant source for HCB and PAH emissions (68% and 8%, respectively).

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).

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 2015, 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 and further investigation is planned to verify 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 2015 are reported in Table 1.2.

Table 1.2 *Emission time series by pollutant*

		1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
SO_X	*Gg*	1,783	1,322	755	408	217	195	177	145	131	123
NO_X	*Gg*	2,032	1,907	1,451	1,233	948	915	852	799	787	763
NMVOC	*Gg*	1,936	1,967	1,516	1,232	1,001	911	907	877	821	842
NH_3	*Gg*	471	451	453	422	389	402	416	403	394	393
CO	*Gg*	7,246	7,297	4,919	3,430	3,059	2,416	2,660	2,489	2,258	2,356
As	*Mg*	36	27	45	40	45	46	45	44	44	45
Cd	*Mg*	10	9	9	8	7	7	7	7	7	6
Cr	*Mg*	91	74	52	59	52	52	50	46	44	45
Cu	*Mg*	136	148	145	149	131	133	128	120	124	120
Hg	*Mg*	12	10	9	10	9	9	8	8	8	8
Ni	*Mg*	113	108	103	108	38	36	34	30	29	30
Pb	*Mg*	4,344	2,037	957	284	266	263	266	257	260	255
Se	*Mg*	9	10	11	12	11	11	11	10	10	10
Zn	*Mg*	966	953	916	987	915	973	941	882	876	860
TSP	*Gg*	323	317	273	244	260	205	236	229	209	221
PM10	*Gg*	271	265	225	198	213	165	192	186	169	179
PM2.5	*Gg*	221	218	189	166	190	143	171	166	150	160
BC	*Gg*	47	46	42	38	32	27	28	26	24	24
PAH	*Mg*	99	101	68	73	96	74	91	86	76	82
Dioxin	*g ITe_q*	503	484	404	327	309	268	287	282	269	280
HCB	*kg*	43	38	25	21	14	17	22	21	20	20
PCB	*kg*	289	301	266	278	211	218	225	204	198	195

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 five years, from 2012 with reference to 2010 emissions, ISPRA shall provide the disaggregation of the national inventory at provincial level as instituted by the Legislative Decree n. 155 of 13th August 2010. 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, 2016).

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 a number of 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 (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 taken into account 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. In particular, 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 sufficient 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
3 Solvent and Other Product Use	Amount of solvent use	National Environmental Publications - Sectoral Industrial Associations International Statistical Yearbooks - UN
4 Agriculture	Agricultural surfaces Production data Number of animals Fertilizer consumption	Agriculture Statistical Yearbooks - National Institute of Statistics Sectoral Agriculture Associations
5 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
6 Waste	Amount of waste	National Waste Cadastre - Institute for Environmental Protection and Research , National Waste Observatory

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; 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, 2017 [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 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 the Italian Emissions Trading Scheme database 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 taken into account 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 the previous year. These data are used for the compilation of the inventory whenever they are complete in terms of sectoral information; in fact, industries communicate figures only if they exceed specific thresholds; furthermore, basic data such as fuel consumption are not supplied 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 taking into account 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 and the Waste Observatory.

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 Tier 1 method described in the EMEP/EEA Guidebook (EMEP/EEA, 2016). 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 2015 (Table 1.5) by pollutant.

The trend analysis has also been applied considering 1990 and 2015. 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%)	1A2f (17.0%)	1A1b (10.8%)	1A3d ii (4.4%)	1A4b i (4.1%)	1B2a iv (3.8%)							83.1
NO_x	1A3b i (26.1%)	1A1a (20.1%)	1A3b iii (16.8%)	1A2f (12.2%)	1A4c ii (5.0%)								80.3
NH_3	3Da2a (21.6%)	3B1a (20.9%)	3B1b (18.0%)	3Da1 (15.6%)	3B3 (7.7%)								83.8
NMVOC	1A3b i (24.7%)	2D3d (14.0%)	1A3b v (9.6%)	1A3b iv (7.9%)	2D3a (6.0%)	1A4b i (5.1%)	2D3g (4.0%)	1A4c ii (3.6%)	2D3i (3.4%)	1B2a v (3.1%)			81.3
CO	1A3b i (62.7%)	1A4b i (10.9%)	1A3b iv (7.0%)										80.5
PM10	1A4b i (24.8%)	1A1a (13.9%)	1A2f (10.6%)	1A3b i (6.9%)	1A4c ii (5.9%)	1A3b iii (5.1%)	1A3b ii (3.7%)	1A3d ii (3.4%)	3B4g ii (3.0%)	1A3b vi (2.9%)			80.1
PM2.5	1A4b i (30.1%)	1A1a (11.3%)	1A2f (8.8%)	1A3b i (8.4%)	1A4c ii (7.2%)	1A3b iii (6.2%)	1A3b ii (4.5%)	1A3d ii (4.2%)					80.9
BC	1A3b i (21.6%)	1A4c ii (19.4%)	1A3b iii (14.8%)	1A3b ii (11.8%)	1A4b i (11.2%)	1A2g vii (5.0%)							83.8
Pb	1A3b i (77.2%)	1A2f (6.1%)											83.3
Cd	1A2f (56.2%)	2C1 (13.2%)	1A4b i (10.1%)	1A4a i (3.8%)									83.4
Hg	1A2f (36.0%)	2B10a (24.2%)	2C1 (19.8%)										80.0
PAH	2C1 (45.5%)	1A4b i (32.1%)	1A1c (8.4%)										86.0
Dioxin	1A2f (23.3%)	1A4a i (20.6%)	1A4b i (13.9%)	2C1 (13.4%)	5C1a (8.5%)	5C1b i (6.2%)							85.9
HCB	3Df (54.2)	5C1b iv (23.9%)	1A2f (11.2%)										89.4
PCB	1A1a (39.0%)	2C1 (31.7%)	1A2f (19.4%)										90.1

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

Table 1.5 *Key categories for the Italian Emission Inventory in 2015*

	Key categories in 2015												Total (%)
SO_x	1A2f (21.8%)	1A3d ii (17.1%)	1B2a iv (14.6%)	1A1a (14.2%)	1A1b (8.3%)	2A1 (5.1%)							81.1
NO_x	1A3b iii (23.8%)	1A3b i (20.5%)	1A3d ii (9.2%)	1A2f (8.5%)	1A3b ii (6.7%)	1A4b i (5.6%)	1A1a (4.8%)	1A4c ii (4.6%)					83.5
NH_3	3Da2a (19.1%)	3B1a (16.6%)	3B1b (16.4%)	3Da1 (15.1%)	3B3 (9.2%)	3B4g ii (3.9%)							80.3
NMVOC	1A4b i (20.5%)	2D3d (18.8%)	2D3a (9.4%)	1A3b v (6.8%)	2D3g (6.2%)	1A3b iv (6.1%)	1A4a i (3.0%)	1A3b i (2.9%)	2D3 i (2.8%)	2H2 (2.6%)			80.1
CO	1A4b i (60.8%)	1A3b i (11.6%)	1A3b iv (6.4%)	1A2f (3.8%)									82.5
PM10	1A4b i (61.1%)	1A3b vi (4.8%)	1A2f (3.8%)	1A3b i (3.1%)	1A3d ii (3.1%)	2C1 (2.6%)	1A3b iii (2.2%)						80.7
PM2.5	1A4b i (67.7%)	1A2f (3.5%)	1A3b i (3.5%)	1A3d ii (3.4%)	1A3b vi (2.9%)								81.1
BC	1A4b i (38.7%)	1A3b i (18.7%)	1A3b iii (10.7%)	1A3b ii (9.3%)	1A4c ii (6.6%)								84.0
Pb	1A2f (37.5%)	1A4a i (26.5%)	2C1 (25.0%)										88.9
Cd	1A4a i (34.0%)	1A2f (32.0%)	2C1 (15.5%)										81.5
Hg	2C1 (31.7%)	1A4a i (28.1%)	1A2f (26.7%)										86.5
PAH	1A4b i (71.7%)	2C1 (10.0%)											81.7
Dioxin	1A4b i (41.2%)	2C1 (27.4%)	1A2f (20.0%)										88.6
HCB	5C1b iv (62.5%)	1A2f (12.8%)	1A4b i (7.9%)										83.3
PCB	2C1 (40.6%)	1A1a (33.6%)	1A2f (9.1%)										83.3

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

Table 1.6 *Key categories for the Italian Emission Inventory in trend 1990-2015*

	Key categories in trend												Total (%)
SO_X	1A1a (35.6%)	1A3d ii (15.7%)	1B2a iv (13.3%)	1A2f (6.0%)	2A1 (4.8%)	1A3b i (4.0%)	1A4a i (3.6%)						82.8
NO_X	1A1a (27.9%)	1A3b iii (12.7%)	1A3b i (10.1%)	1A3d ii (8.1%)	1A4a i (7.1%)	1A2f (6.9%)	1A3b ii (6.2%)	1A4b i (5.5%)					84.5
NH_3	3B1a (19.5%)	3Da2a (11.9%)	3Da2c (10.9%)	3B4a (9.8%)	3B1b (7.5%)	3B4g i (7.1%)	3B3 (6.9%)	1A3b i (6.3%)	3B4g ii (6.0%)				85.8
NMVOC	1A3b i (31.0%)	1A4b i (21.9%)	2D3d (8.3%)	2D3a (4.8%)	1A4a i (4.1%)	1A3b v (3.9%)	1A4c ii (3.6%)	2D3g (3.1%)					80.7
CO	1A3b i (44.8%)	1A4b i (43.7%)											87.4
PM10	1A4b i (43.7%)	1A1a (16.2%)	1A2f (8.2%)	1A4c ii (5.2%)	1A3b i (4.5%)	1A3b iii (3.4%)							81.3
PM2.5	1A4b i (45.8%)	1A1a (13.4%)	1A4c ii (6.7%)	1A2f (6.5%)	1A3b i (6.1%)	1A3b iii (4.6%)							82.9
BC	1A4b i (42.8%)	1A4c ii (19.9%)	1A3b iii (6.4%)	1A2g vii (5.9%)	1A3b i (4.4%)	1A3b ii (3.9%)							83.3
Pb	1A3b i (42.2%)	1A2f (17.1%)	1A4a i (14.4%)	2C1 (12.9%)									86.6
Cd	1A4a i (43.0%)	1A2f (34.5%)	1A4b i (4.1%)										81.6
Hg	1A4a i (32.6%)	2B10a (30.8%)	2C1 (15.5%)	1A2f (12.1%)									91.1
PAH	1A4b i (43.6%)	2C1 (39.1%)											82.8
Dioxin	1A4b i (30.1%)	1A4a i (21.7%)	2C1 (15.5%)	5C1a (9.4%)	5C1b i (6.8%)								83.5
HCB	3Df (49.1%)	5C1b iv (36.2%)											85.3
PCB	1A2 (26.3%)	2C1 (22.9%)	1A4a i (14.4%)	1A1a (14.1%)	1A4b i (12.6%)								90.3

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

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, 2017 [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.

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 the past years, ISPRA has finalised the provincial inventory at local scale for the years 1990, 1995, 2000, 2005 and 2010 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 the 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* 2017 (ISPRA, 2017 [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 stationary combustion in manufacturing industries and construction are not split among the relevant production sectors but included in category 1.A.2.f as a total; 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. Emissions from 3.B.4.g iii turkeys are included in 3.B.4.g iv other poultry.

There are a few emission sources not assessed yet: PM, Pb and Cd non exhaust emissions from 1.A.3.b vii, road abrasion, 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, 2016), need further assessment for the applicability to the national circumstances. PAH emissions are not detailed in the four indicator compounds but accounted for as a total because for many categories emission factors are not available by compound. Black carbon emissions from 1.A.3.b vi automobile tyre and brake wear, have not been estimated and will be included in the next submission.

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.

NH_3, SO_2, HMs and POPs emissions from field burning of agriculture waste (4F category) seem not to occur: further assessment will be carried out analysing in depth the studies providing emission factors in the EMEP/EEA Guidebook.

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 2015. Figure 2.1 also illustrates the share of SO_X emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

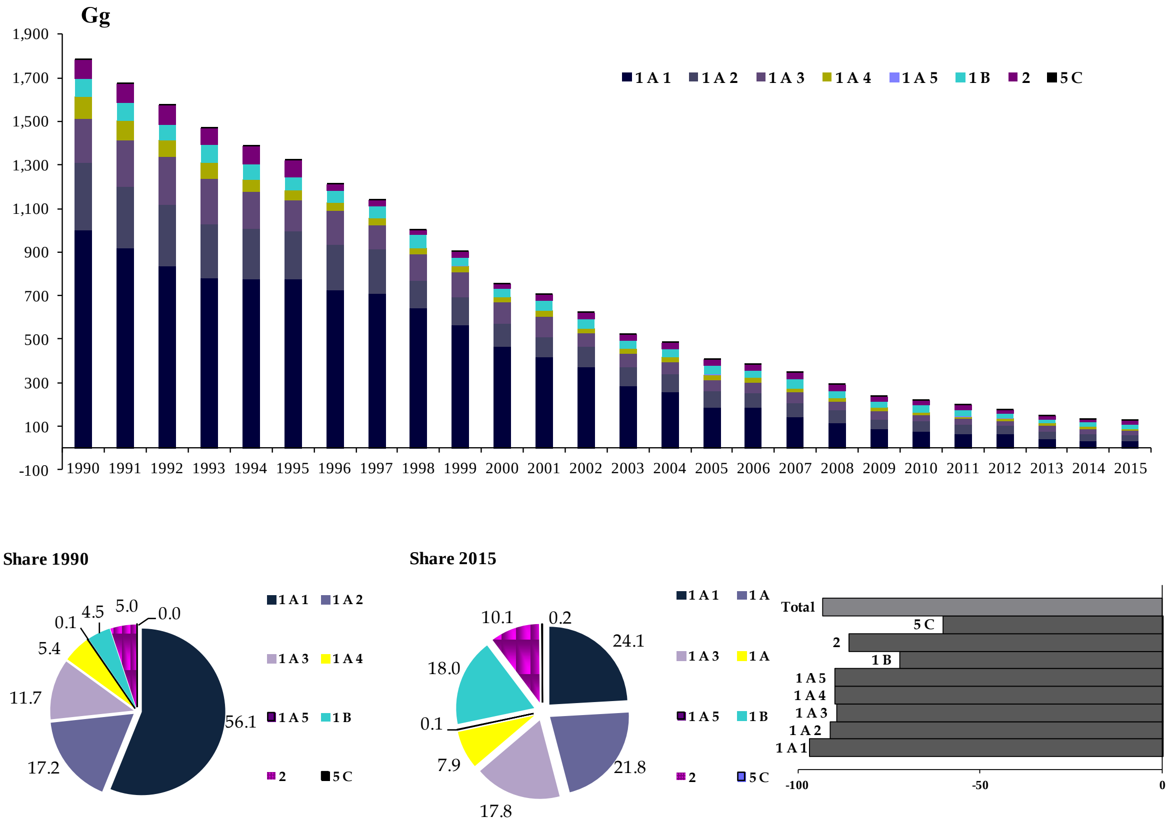

Figure 2.1 *SO_X emissions trend, percentage share by sector and variation 1990-2015*

Table 2.1 *SO_X emission trend from 1990 to 2015 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	1,001	776	467	187	77	66	65	45	31	30
Non industrial combustion plants	82	32	25	22	12	9	10	10	9	10
Combustion - Industry	303	220	107	75	46	42	37	33	32	27
Production processes	157	126	51	60	46	46	36	32	32	30
Road transport	130	72	12	2	0	0	0	0	0	0
Other mobile sources and machinery	98	84	84	51	29	27	24	23	23	22
Waste treatment and disposal	13	11	10	11	7	5	5	2	3	4
Total	***1,783***	***1,322***	***755***	***408***	***217***	***195***	***177***	***145***	***131***	***123***

Figures show a general decline of SO_X emissions during the period, from about 1,800 Gg in 1990 to 123 Gg in 2015. The national target of SO_X emissions, set by the National Emission Ceilings Directive at 475 Gg for 2010 (EC, 2001) was reached as reported in the previous year submissions and continues to be respected after this year revision of the time series. The new target established for 2020 in the framework of the UNECE/CLRTAP Convention, equal for Italy to 65% of 2005 emissions, has been already reached.

The decreasing trend is determined mainly by the reduction in emissions from *combustion in energy* (-97%) and in *industry* (-91%), representing in 2015 about 24%, and 22% of the total, respectively. Emissions deriving from *non industrial combustion plants* and *road transport* show a strong decrease too (-88% and -99.7%, respectively), but these emissions represent only about 8% and 0.3% of the total in 2015. *Production processes* and *other mobile sources and machiner*y also present a significant decreasing trend, showing an influence on the total of 25% and 18% and dropping by about -81% and -78%, respectively.

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 has 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, a number of 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.

Combustion in industry

Emissions from this sector show the same trend of reduction as the category previously analyzed, 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 12^{th} July 1990 (Ministerial Decree of 12^{th} 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 with regard to 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 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 the introduction of 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 1990-2015, from 2,032 Gg to 763 Gg. Figure 2.2 and Table 2.2 show emission figures from 1990 to 2015. Figure 2.2 also illustrates the share of NO_X emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

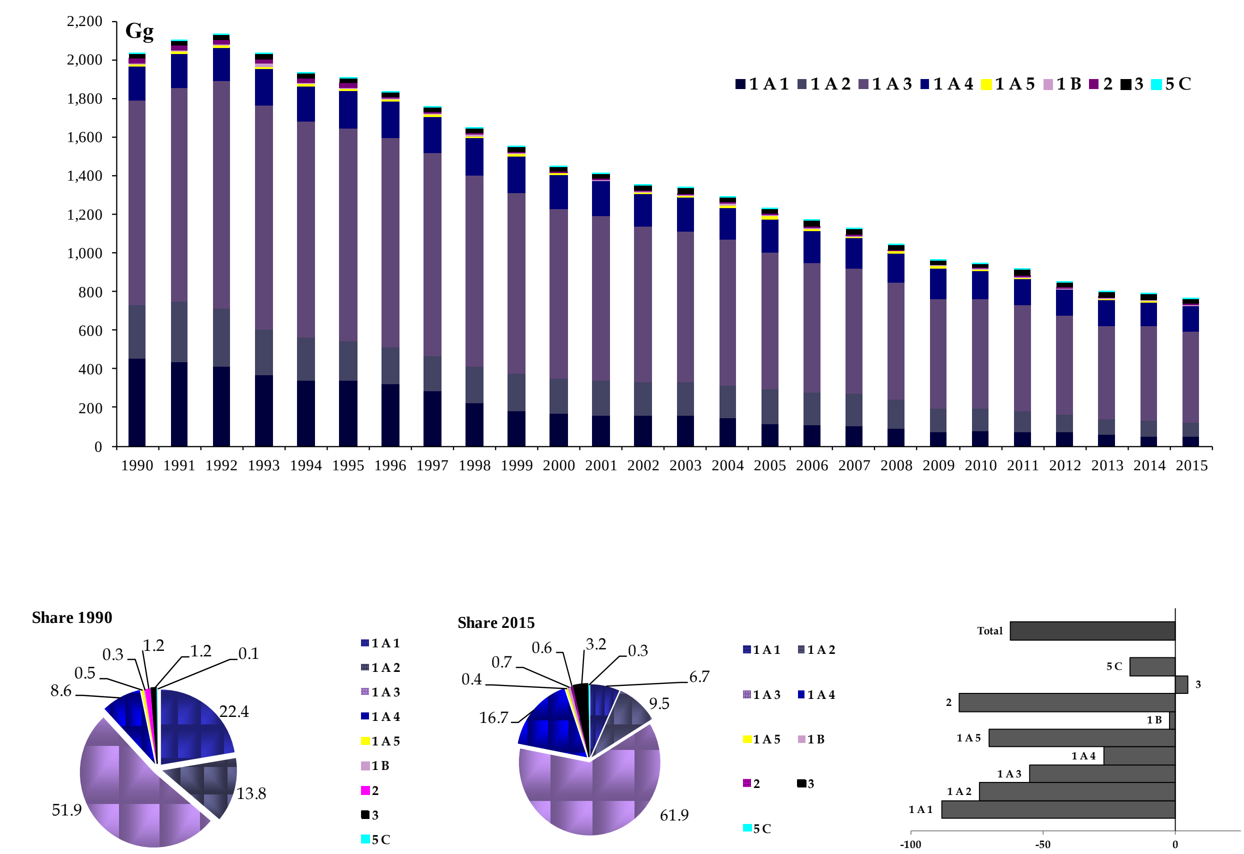

Figure 2.2 *NO_X emission trend, percentage share by sector and variation 1990-2015*

Table 2.2 *NO_X emission trend from 1990 to 2015 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	457	344	173	118	81	75	73	61	52	52
Non industrial combustion plants	65	66	70	80	89	80	84	89	81	87
Combustion - Industry	249	180	152	153	100	98	82	73	70	65
Production processes	30	31	9	16	10	11	10	9	10	9
Road transport	943	999	758	605	461	453	423	398	407	394
Other mobile sources and machinery	261	258	260	233	183	166	149	141	137	129
Waste treatment and disposal	3	3	3	3	3	3	3	3	2	2
Agriculture	24	25	26	26	22	30	27	25	26	25
Total	***2,032***	***1,907***	***1,451***	***1,233***	***948***	***915***	***852***	***799***	***787***	***763***

Total emissions show a reduction of about 62% from 1990 to 2015, 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.

The main source of emissions is *road transport* (about 52% in 2015), which shows a reduction of 58% between 1990 and 2015; *other mobile sources and machinery* in 2015 contributes to the total emissions for 17% and have reduced by 51% from 1990. Combustion in energy and in industry shows a decrease of about 89% and 74%, respectively, having a share on the total of about 7% and 8% in 2015, respectively. Among the sectors concerned, the only one which highlights an increase in emissions is *non industrial combustion plants* showing an increase by 35%, accounting for 11% 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. 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 due to the fact that 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.

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 2015 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 1990-2015, from 471 Gg to 393 Gg. Figure 2.3 and Table 2.3 report the emission figures from 1990 to 2015. Figure 2.3 also illustrates the share of NH_3 emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

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 in 2014.

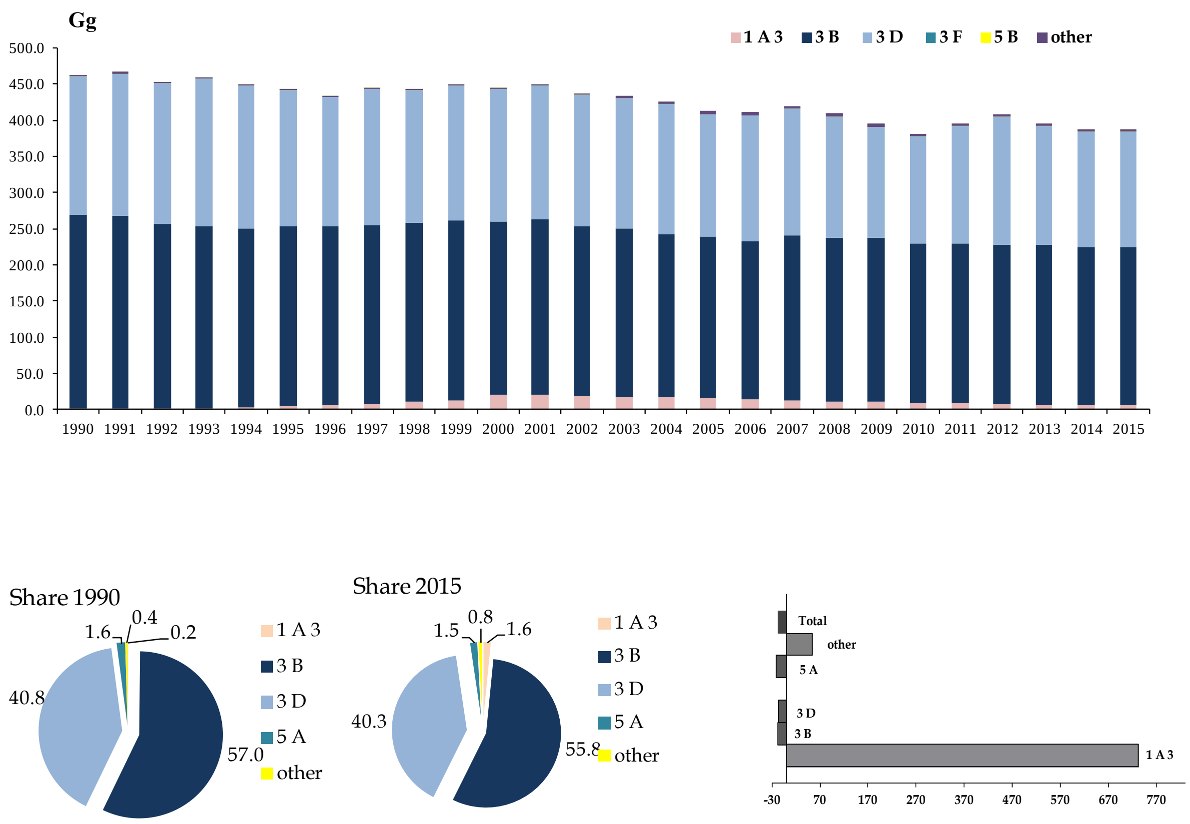

Figure 2.3 *NH_3 emission trend, percentage share by sector and variation 1990-2015*

Table 2.3 *NH_3 emission trend from 1990 to 2015 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Non industrial combustion plants	1.1	1.1	1.0	1.0	1.8	1.1	1.7	1.7	1.5	1.7
Combustion - Industry	0.1	0.1	0.1	3.5	1.2	1.3	1.0	1.0	0.9	0.7
Production processes	0.8	0.4	0.3	0.5	0.5	0.4	0.5	0.4	0.4	0.5
Road transport	0.7	5.1	20.2	14.9	9.2	8.5	7.1	6.8	6.4	6.2
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	7.8	7.2	8.4	8.5	7.7	7.4	7.4	6.7	6.6	6.2
Agriculture	460	437	423	393	369	383	398	386	378	378
Total	***471***	***451***	***453***	***422***	***389***	***402***	***416***	***403***	***394***	***393***

In 2015 *agriculture* is the main source of emissions, with a 96% contribution out of the total NH_3 emissions; from 1990 to 2015 emissions from this sector show a decrease of about 16%. Emissions from *road transport* show a strong increase, but the share on the total is less than 2%. Emissions from *waste treatment and disposa*l, accounting also only for 2% of the total, show a decrease of about 20%. Emissions from *non industrial combustion plants* show a relevant increase, but in 2015 the contribution to total emissions is 0.4%. Emissions from *combustion in energy and transformation industries* as emissions from *combustion in industry* show a significant increase, but their contribution to total emissions is not relevant. Emissions from *production processes* show a reduction of about 40%, but also this contribution is irrelevant.

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). Emission trend of the *waste* sector is driven by the amount of waste disposal in landfills. 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.

2.1.4 *Non methane volatile organic compounds (NMVOC)*

The national atmospheric emissions of NMVOC show a decreasing trend in the period 1990-2015. Figure 2.4 and Table 2.4 illustrate the emissions values from 1990 to 2015. Figure 2.4 also illustrates the share of NMVOC emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

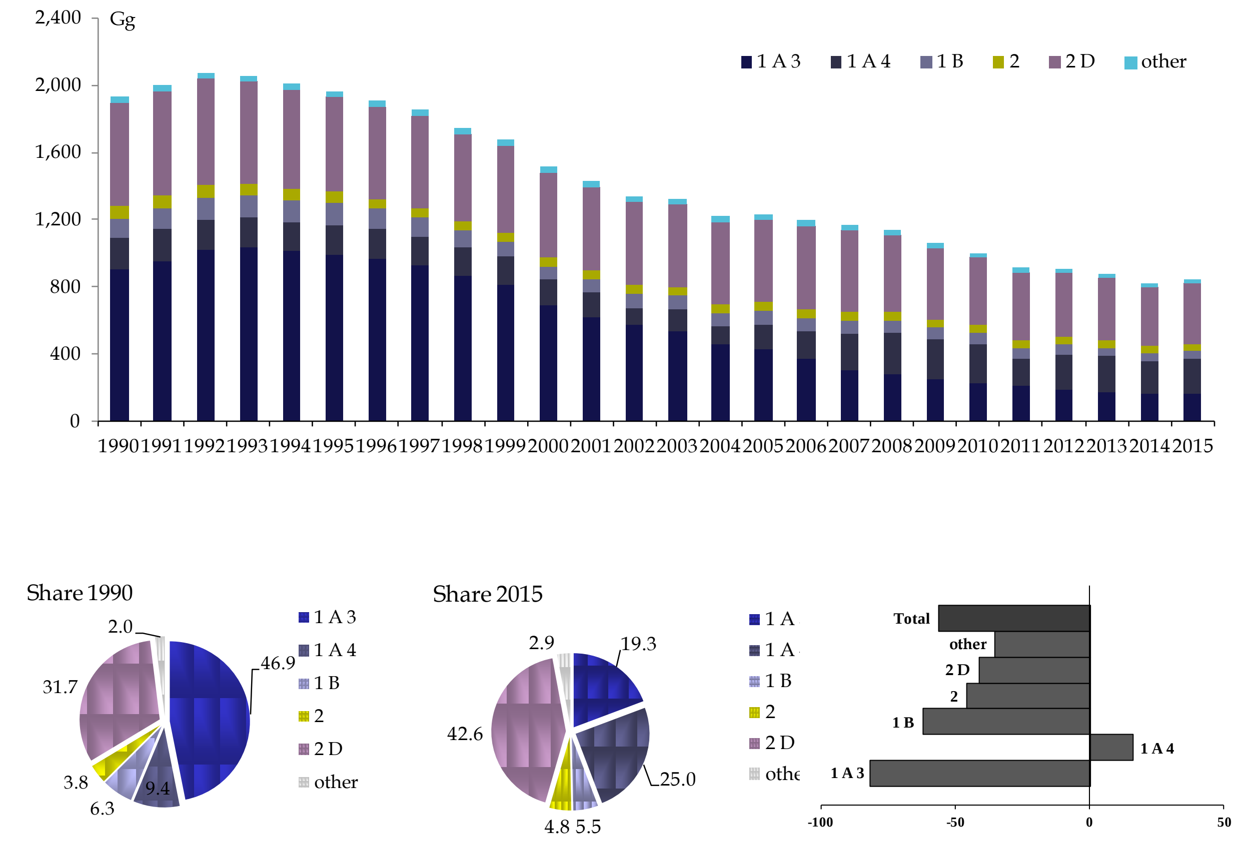

Figure 2.4 *NMVOC emission trend, percentage share by sector and variation 1990-2015*

The global emission trend shows a reduction of about 56% between 1990 and 2015, from 1,936 Gg to 842 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.

Solvent and other product use is the main source of emissions, contributing to the total with 42% and showing a decrease of about 42%. The main reductions relate to the *road transport* sector (-83%), accounting for 17% of the total and to the sector of *extraction and distribution of fossil fuels/geothermal energy* (-59%), accounting only for 4%. Emissions from *other mobile sources and machinery*, accounting for 4% of the total, decrease of about 77%. Emissions from *non industrial combustion plants* show the largest increase (94%), accounting for 24%. Emissions from *waste treatment and disposal* and *combustion in industry* show a decrease of about 23% and 9%, respectively, but both these sources account only for about 1%. Emissions from *agriculture* decrease of about 6%, but their contribution is irrelevant.

Details on the sectoral emission trend and respective variation are outlined in the following sections.

Table 2.4 *NMVOC emission trend from 1990 to 2015 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	8	7	6	6	5	5	4	4	3	4
Non industrial combustion plants	103	113	115	125	220	147	201	203	179	199
Combustion - Industry	7	8	8	8	6	7	6	6	7	7
Production processes	114	103	88	92	74	71	63	58	57	55
Extraction and distribution of fossil fuels	91	104	57	54	49	44	45	41	40	38
Solvent and other product use	604	555	492	477	390	398	374	367	344	353
Road transport	860	939	636	379	191	181	164	150	146	144
Other mobile sources and machinery	134	122	99	76	52	45	35	34	33	31
Waste treatment and disposal	14	14	14	15	13	13	13	12	11	11
Agriculture	1	1	1	1	1	1	1	1	1	1
Total	***1,936***	***1,967***	***1,516***	***1,232***	***1,001***	***911***	***907***	***877***	***821***	***842***

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 equipments 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 the 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.

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 1990-2015, from 7,246 Gg to 2,356 Gg. The emission figures from 1990 to 2015 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 2015, as well as the total and sectoral variation from 1990 to 2015.

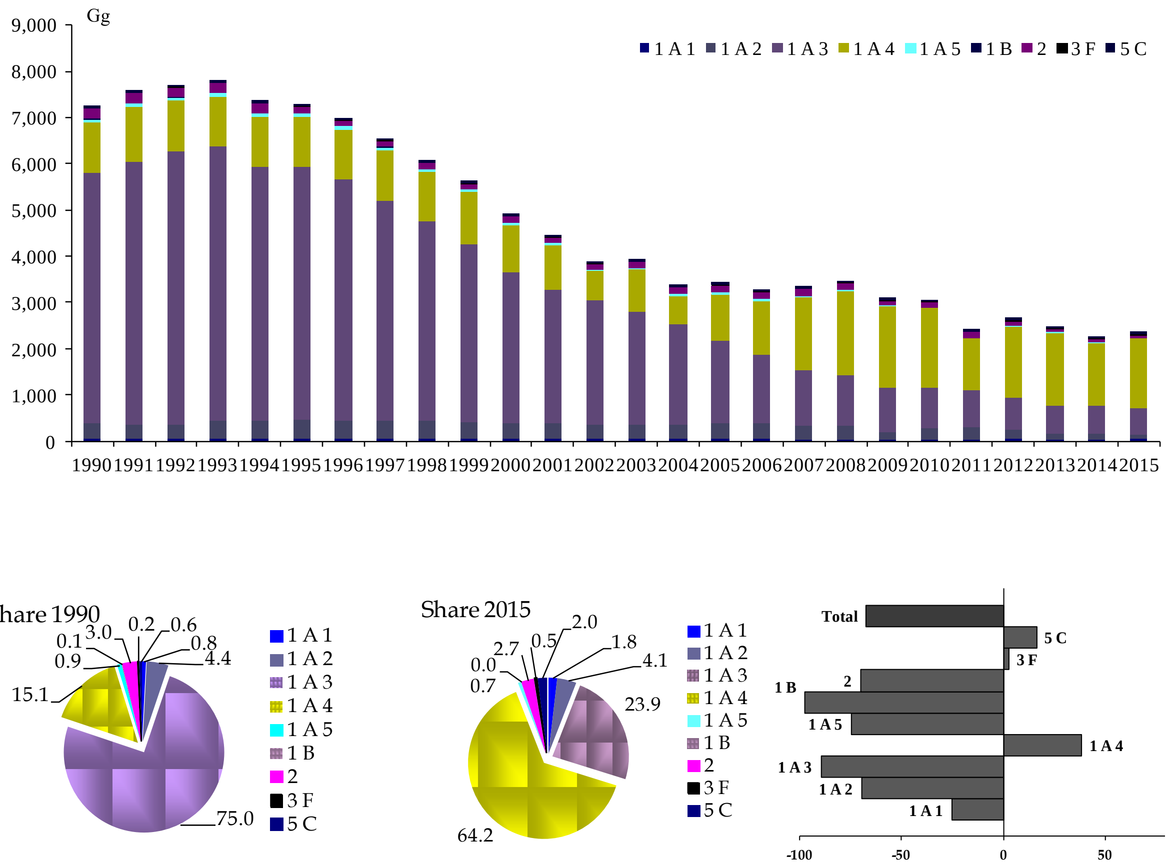

Figure 2.5 *CO emission trend, percentage share by sector and variation 1990-2015*

Table 2.5 *CO emission trend from 1990 to 2015 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	59	54	56	54	34	33	51	36	37	43
Non industrial combustion plants	795	894	913	931	1,665	1,084	1,510	1,513	1,308	1,467
Combustion - Industry	306	411	313	326	233	265	191	115	118	89
Production processes	224	140	129	144	105	118	108	76	72	64
Road transport	5,329	5,336	3,148	1,648	768	685	607	554	525	495
Other mobile sources and machinery	480	402	303	263	194	172	131	136	143	137
Waste treatment and disposal	41	47	45	50	47	47	48	45	42	47
Agriculture	12	12	12	13	12	12	13	12	12	13
Total	**7,246**	**7,297**	**4,919**	**3,430**	**3,059**	**2,416**	**2,660**	**2,489**	**2,258**	**2,356**

The decrease in emissions (-67%) 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 2015 of about 89%. Specifically by sector, emissions from *road transport* and *other mobile sources and machinery*, accounting in 2015 respectively for 21% and 6% of the total, show a decrease from 1990 to 2015 of about 91% and 71% respectively. On the other hand, emissions from *non industrial combustion plants*, representing about 62 % of the total in 2015, show a strong increase between 1990 and 2015, equal to 85% due to the increase of wood combustion for residential heating.

Figures show an increase in emissions from *waste treatment and disposal* too (16%), whose share is 2% of the total and no variations 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 1990-2015, from 271 Gg to 179 Gg. Figure 2.6 and Table 2.6 illustrate the emission trend from 1990 to 2015. Figure 2.6 also illustrates the share of PM10 emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

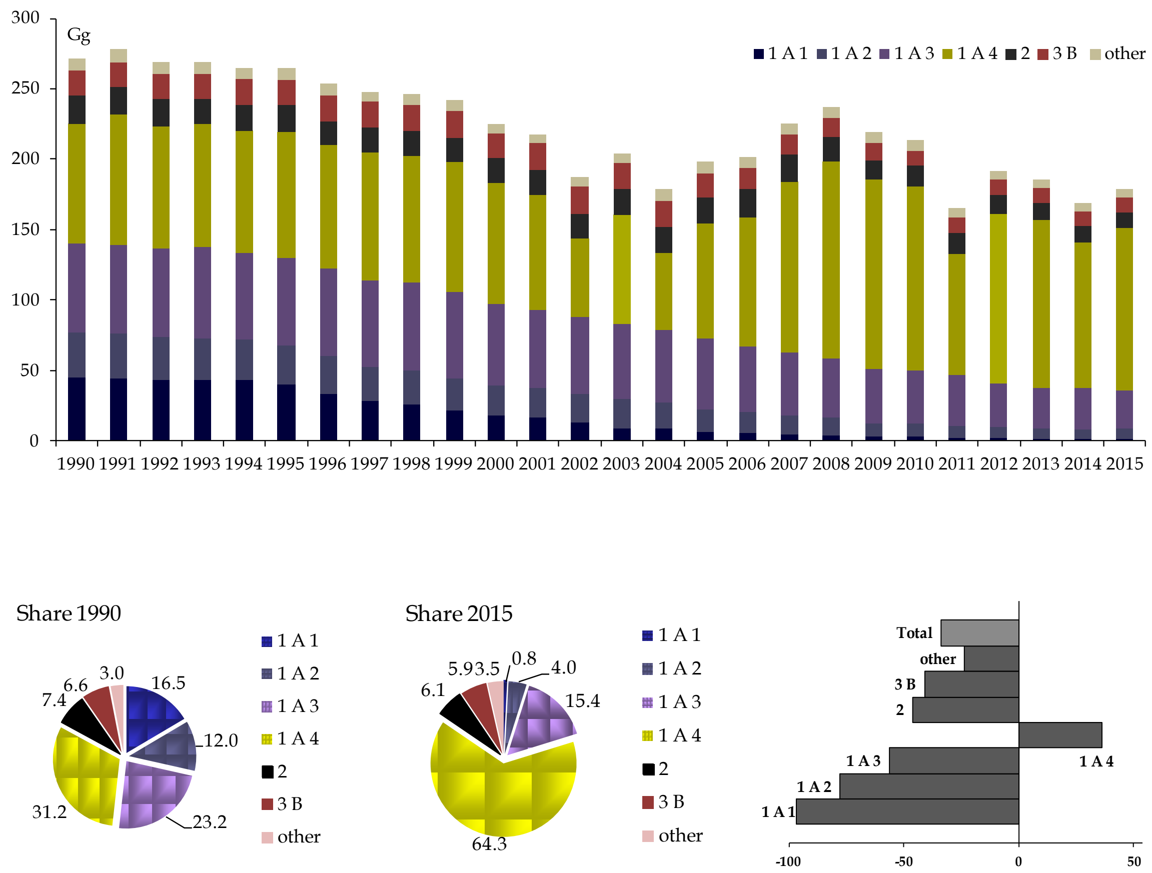

Figure 2.6 *PM10 emission trend, percentage share by sector and variation 1990-2015*

Table 2.6 *PM10 emission trend from 1990 to 2015(Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	45	40	18	6	3	2	2	1	1	1
Non industrial combustion plants	68	71	70	69	124	80	115	115	99	112
Combustion - Industry	29	26	17	14	8	8	7	6	6	7
Production processes	22	20	19	20	16	16	14	13	12	11
Extraction and distribution of fossil fuels	1	1	1	1	1	1	1	1	1	1
Solvent and other product use	0.04	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Road transport	53	52	48	41	30	29	25	23	24	22
Other mobile sources and machinery	32	32	30	25	16	14	12	11	11	10
Waste treatment and disposal	2	3	2	3	3	3	3	2	2	3
Agriculture	20	20	20	19	13	13	13	13	13	13
Total	***271***	***265***	***225***	***198***	***213***	***165***	***192***	***186***	***169***	***179***

From 1990 to 2015 the trend shows a reduction of about 34%. A considerable amount of emissions is mostly to be attributed to *non industrial combustion plant* (62% in 2015) which is the only sector increasing its emissions, about 65%, due to the increase of wood combustion for residential heating.

Road transport accounts for 12% of total emissions in 2015 and decrease by 59% due to the introduction of the relevant European Directives controlling and limiting PM emissions at the car exhaust pipe.

In 2015 *other mobile sources and machinery*, accounting for 6% of the total, shows a reduction of about 69% 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 77%. Emissions from *production processes* accounting for 6% of the total in 2015 decrease of about 49% between 1990 and 2015. The largest decrease (-97%) is observed in emissions deriving from *combustion in energy and transformation industries*, whose contribution to total emissions is almost irrelevant in 2015 and equal to 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 2015, with a variation from 221 Gg to 160 Gg. Figure 2.7 and Table 2.7 illustrate the emission trend from 1990 to 2015. Figure 2.7 also illustrates the share of PM2.5 emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

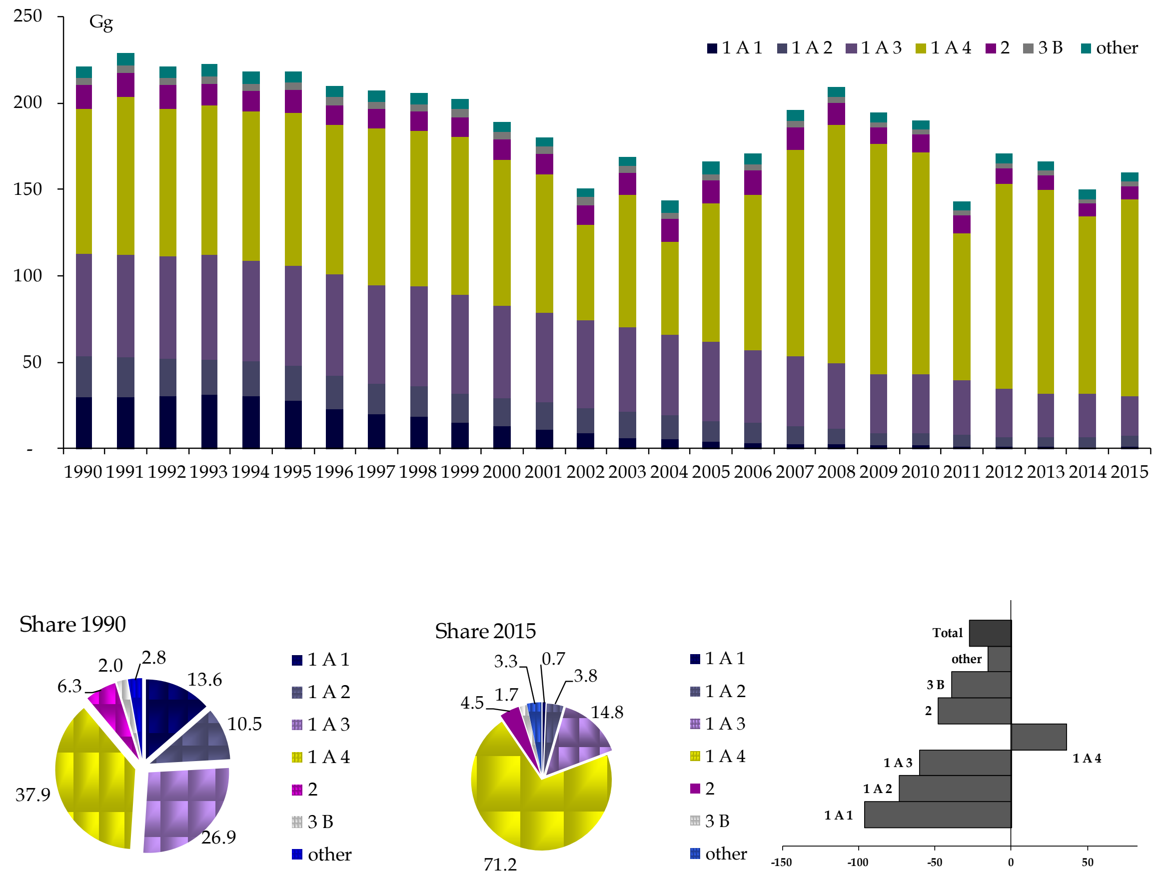

Figure 2.7 *PM2.5 emission trend, percentage share by sector and variation 1990-2015*

Table 2.7 *PM2.5 emission trend from 1990 to 2015 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	30	28	13	4	2	1	1	1	1	1
Non industrial combustion plants	67	71	69	68	122	79	114	114	98	110
Combustion - Industry	20	18	12	10	6	6	5	5	5	6
Production processes	15	13	12	13	11	11	10	8	8	8
Extraction and distribution of fossil fuels	0.07	0.06	0.06	0.08	0.07	0.08	0.08	0.07	0.06	0.06
Solvent and other product use	0.04	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Road transport	50	48	44	37	26	25	22	19	20	18
Other mobile sources and machinery	32	32	30	25	16	14	12	11	11	10
Waste treatment and disposal	2	2	2	2	2	2	2	2	2	2
Agriculture	6	6	6	6	5	5	5	5	5	5
Total	***221***	***218***	***189***	***166***	***190***	***143***	***171***	***166***	***150***	***160***

In 2015, 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.

Total emissions show a global reduction from 1990 to 2015 of about 28%. Specifically, emissions from *road transport*, accounting for 11% of total emissions, decrease of about 64%. Emissions from *other mobile sources and machinery* show a reduction of 69%, accounting in 2015 for 6% of total emissions. Emissions from *non industrial combustion plants* and from *combustion in industry* account for 69% and 4% of the total respectively, but while the former shows an increase of about 65%, the latter decreases by about 71%. Emissions from *waste treatment and disposal*, accounting for 1% of the total in 2015, show an increase of about 10%. The largest decrease is observed for *combustion in energy* and *transformation industries* (-96%), being the influence on the total in 2015 equal to 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 2015, with a variation from 47 Gg to 24 Gg. Figure 2.7 and Table 2.7 illustrate the emission trend from 1990 to 2015. Figure 2.7 also illustrates the share of BC emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

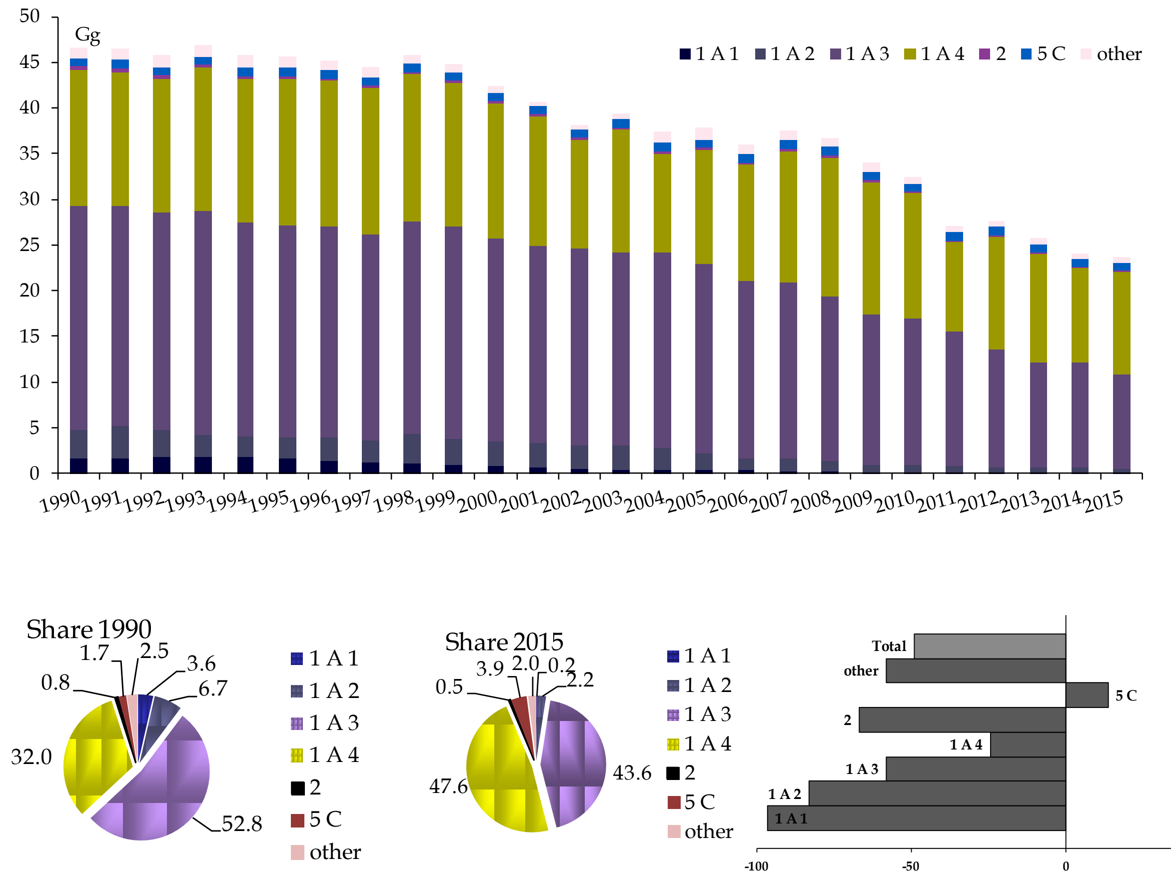

Figure 2.8 *BC emission trend, percentage share by sector and variation 1990-2015*

Table 2.8 *BC emission trend from 1990 to 2015 (Gg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Combustion in energy and transformation industries	2	2	1	0.3	0.3	2	2	2	0.04	0.05
Non industrial combustion plants	5	6	6	6	10	7	10	10	8	9
Combustion - Industry	1	1	0.4	0.4	0.2	0.2	0.2	0.2	0.2	0.2
Production processes	1	1	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2
Extraction and distribution of fossil fuels	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Road transport	23	22	21	19	15	14	12	10	10	9
Other mobile sources and machinery	14	14	13	11	6	5	5	4	4	3
Waste treatment and disposal	1	1	1	1	1	1	1	1	1	1
Agriculture	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	***47***	***46***	***42***	***38***	***32***	***27***	***28***	***26***	***24***	***24***

Total emissions show a global reduction from 1990 to 2015 of about 49%. Specifically, emissions from *road transport*, accounting for 39% of total emissions, decrease of about 60%. Emissions from *other mobile sources and machinery* show a reduction of 76%, accounting in 2015 for 14% of total emissions. Emissions from *non industrial combustion plants* and from *combustion in industry* account for 40% and 1% of the total respectively, but while the former shows an increase of about 73%, the latter decreases by about 70% as well as *industrial processes*. Emissions from *waste treatment and disposal*, accounting for 4% of the total in 2015, show an increase of about 14%. The largest decrease is observed for *combustion in energy* and *transformation industries* (-97%), being the influence on the total in 2015 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 2015 of lead, cadmium and mercury emissions.

2.3.1 Lead (Pb)

The national atmospheric emissions of lead show a strong decreasing trend (-94%) between 1990 and 2015, varying from 4,344 Mg to 255 Mg. Figure 2.9 and Table 2.9 illustrate the emission trend from 1990 to 2015. Figure 2.9 also illustrates the share of Pb emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

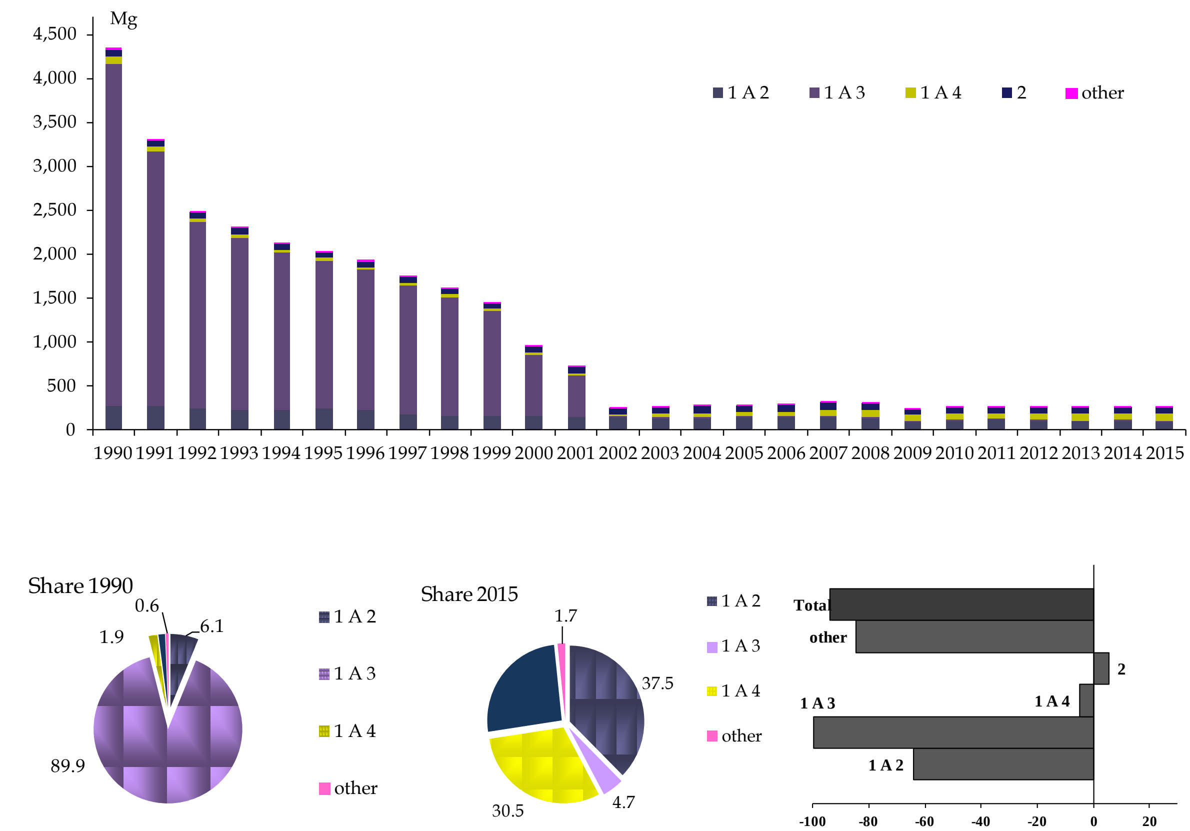

Figure 2.9 *Pb emission trend, percentage share by sector and variation 1990-2015*

Table 2.9 *Pb emission trend from 1990 to 2015 (Mg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Mg					
Combustion in energy and transformation industries	4	4	4	4	3	3	3	3	3	3
Non-industrial combustion plants	14	17	22	46	74	57	68	74	75	78
Combustion - industry	263	235	153	142	104	111	107	98	101	96
Production processes	64	68	67	74	70	77	73	68	68	66
Road transport	3,851	1,664	694	12	12	12	11	11	11	11
Other mobile sources and machinery	142	44	13	1	1	1	1	1	1	1
Waste treatment and disposal	6	5	3	4	2	2	3	3	1	1
Total	***4,344***	***2,037***	***957***	***284***	***266***	***263***	***266***	***257***	***260***	***255***

In 2015 emissions from *combustion in industry* have the most significant impact on the total (37%) and show a reduction of about 64%; this reduction is to be attributed primarily to *processes with contact,* which contribute with 58% 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 4%, and represent 26% of the total. Emissions from *non industrial combustion plants* show a strong increase and represent, in 2015, 30% 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 slight decreasing trend. Figure 2.10 and Table 2.10 illustrate the emission trend from 1990 to 2015. Figure 2.10 also illustrates the share of Cd emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

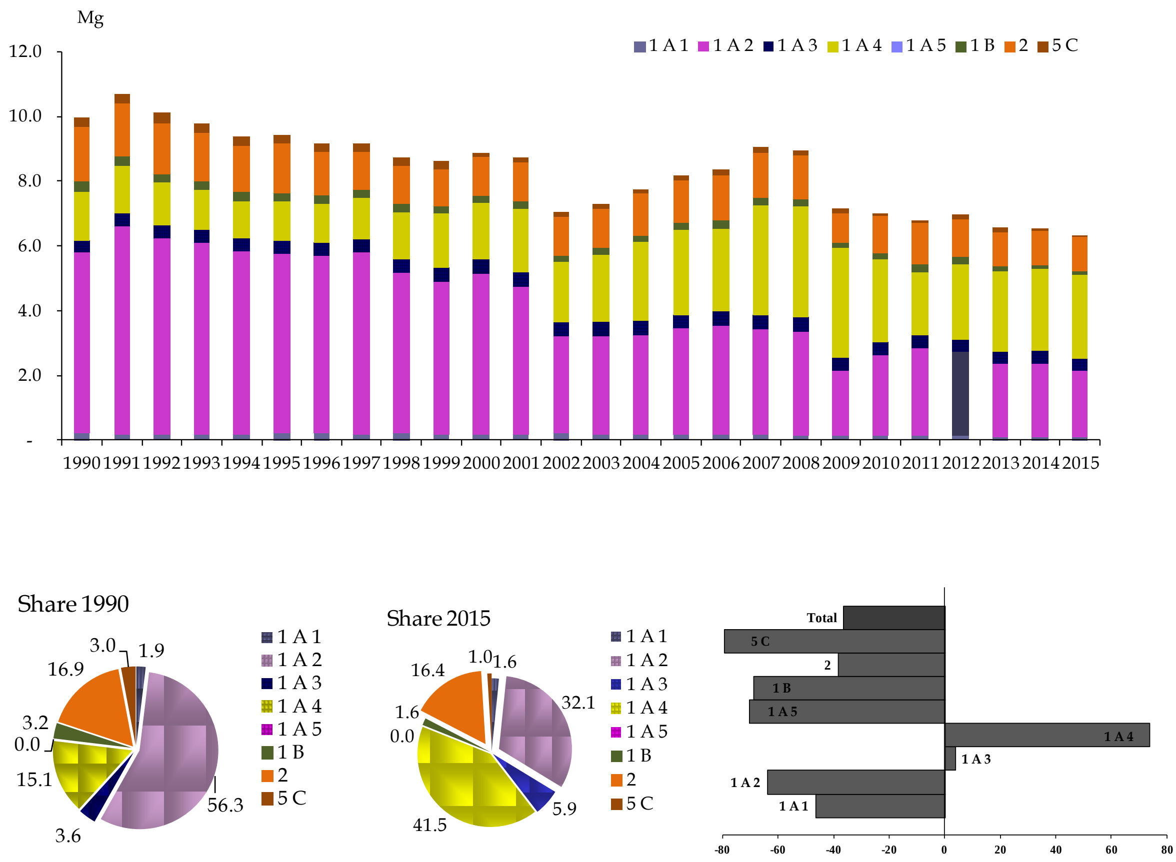

Figure 2.10 *Cd emission trend, percentage share by sector and variation 1990-2015*

Table 2.10 *Cd emission trend from 1990 to 2015 (Mg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					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	2.6	1.9	2.3	2.5	2.5	2.6
Combustion - industry	5.6	5.6	5.0	3.3	2.5	2.7	2.6	2.3	2.3	2.0
Production processes	2.0	1.8	1.4	1.5	1.4	1.5	1.4	1.2	1.2	1.1
Road transport	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3	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	0.3	0.3	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Total	***10.0***	***9.4***	***8.9***	***8.2***	***7.0***	***6.8***	***7.0***	***6.6***	***6.5***	***6.3***

Emissions show a global reduction of 37% between 1990 and 2015, from 10.0 Mg to 6.3 Mg, mainly driven by the reduction of emissions in the non ferrous metal industry, with the installation of the relevant abatement technologies. Among the most significant variations, emissions from *combustion in industry* and from *non industrial combustion plants* represent 32% and 41% of the total respectively, showing the former a decrease (-64%) and the latter an increase (74%). Emissions from *production processes* decrease by about 43% and represent 18% of the total. Emissions from *waste treatment and disposal* (i.e. waste incineration), accounting for 1% of the total, register a reduction of about 80%. A sector which show an increase in emissions is *road transport* (+6%) accounting for 6% of the total levels.

2.3.3 Mercury (Hg)

The national atmospheric emissions of mercury show a quite stable trend in the period 1990-2015. Figure 2.11 and Table 2.11 illustrate the emission trend from 1990 to 2015. Figure 2.11 also illustrates the share of Hg emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

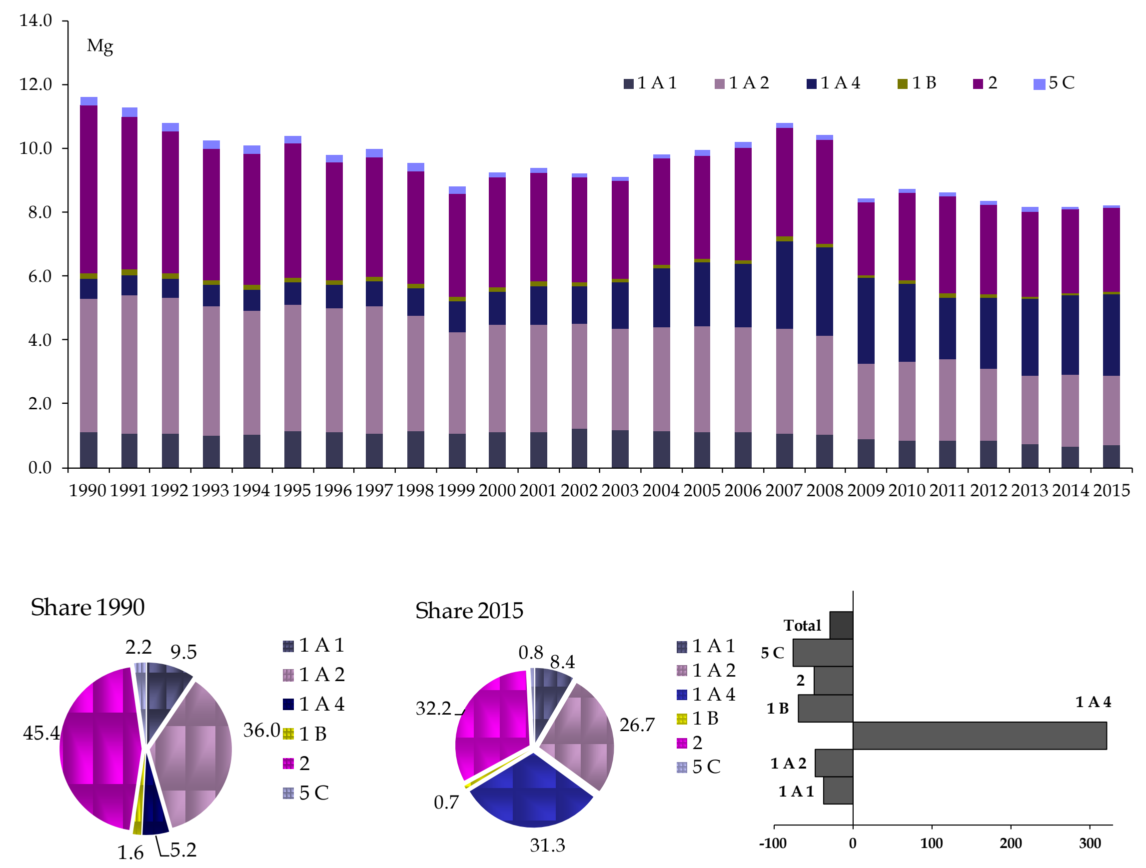

Figure 2.11 *Hg emission trend, percentage share by sector and variation 1990-2015*

Table 2.11 *Hg emission trend from 1990 to 2015 (Mg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
			Mg							
Combustion in energy and transformation industries	1.1	1.1	1.1	1.1	0.9	0.9	0.9	0.7	0.7	0.7
Non-industrial combustion plants	0.6	0.7	1.0	2.0	2.4	1.9	2.2	2.4	2.5	2.6
Combustion - industry	4.2	4.0	3.4	3.4	2.5	2.5	2.2	2.1	2.3	2.2
Production processes	5.5	4.4	3.6	3.4	2.9	3.2	2.9	2.7	2.7	2.7
Waste treatment and disposal	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Total	***11.6***	***10.4***	***9.2***	***9.9***	***8.7***	***8.6***	***8.4***	***8.2***	***8.2***	***8.2***

Emission trend shows a global reduction of about 29% from 1990 to 2015, varying from 11.6 Mg to 8.2 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 23% and decreasing by 46%; emissions from *production process - processes in iron and steel industries and collieries*, representing 32% of the total and increasing by 7%; emissions from *non industrial combustion plants* which represent 31% of the total and showing the strongest increase (321%). Emissions deriving from *combustion in energy and transformation industries*, accounting for 8%, show a 37% reduction. Emissions from *production process - processes in inorganic chemical industries*, contributing to the total less than 1%, show a large reduction, equal to 99% totally due to the technological changes for the production of chlorine. Emissions from *waste treatment and disposal*, contributing to the total only for 1%, show a large reduction, equal to 76%.

2.4 Persistent organic pollutants (POPs)

In this section, the most significant peculiarities of polycyclic aromatic hydrocarbons and dioxins, occurred between 1990 and 2015, will be presented.

2.4.1 Polycyclic aromatic hydrocarbons (PAH)

The national atmospheric emissions of polycyclic aromatic hydrocarbons decreased from 99 Mg to 82 Mg between 1990 and 2015. Figure 2.12 and Table 2.12 illustrate the emission trend from 1990 to 2015. Figure 2.12 also illustrates the share of PAH emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

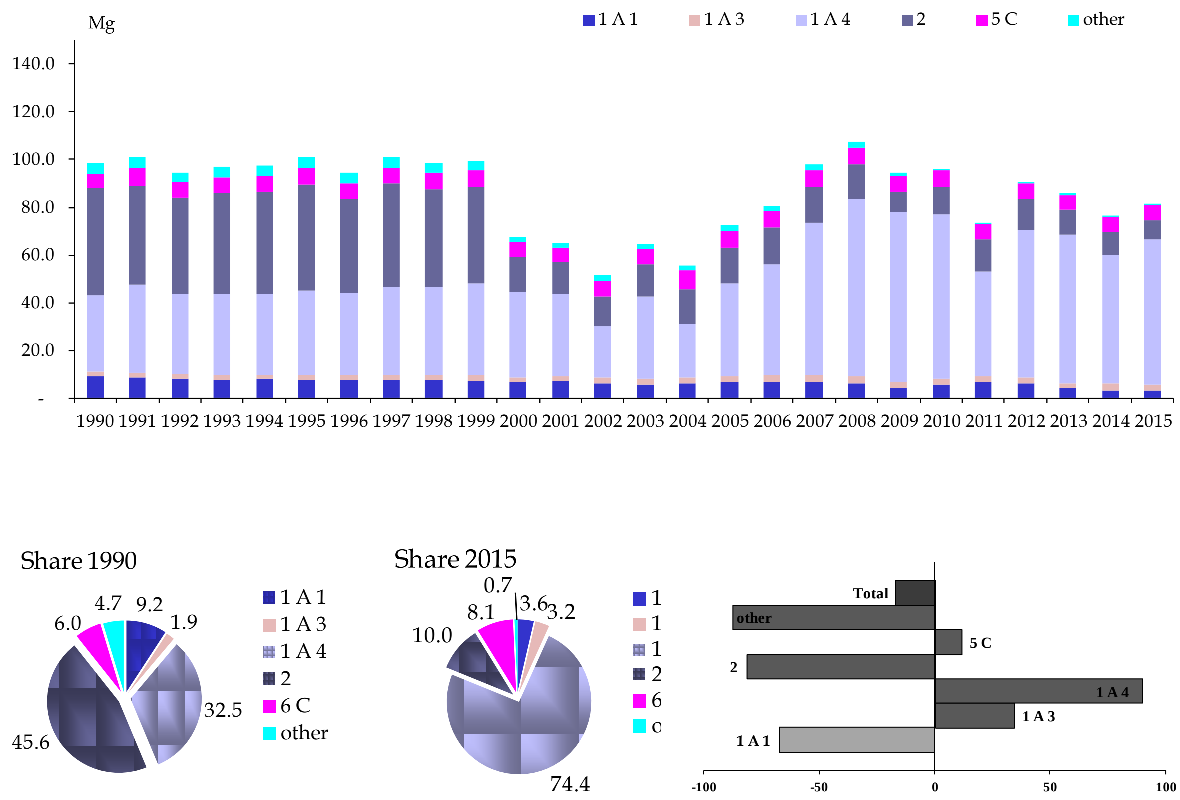

Figure 2.12 *PAH emission trend, percentage share by sector and variation 1990-2015*

Table 2.12 *PAH emission trend from 1990 to 2015 (Mg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Mg					
Combustion in energy and transformation industries	9	8	7	6	6	7	6	4	3	3
Non-industrial combustion plants	32	35	36	39	68	44	62	62	54	61
Combustion - industry	5	5	2	2	0.4	0.5	0.5	1	1	1
Production processes	45	45	14	15	12	14	13	10	10	8
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	2	2	2	2	3	3	2	2	3	3
Other mobile sources and machinery	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.2
Waste treatment and disposal	6	7	6	7	7	7	7	6	6	7
Total	***99***	***101***	***68***	***73***	***96***	***74***	***91***	***86***	***76***	***82***

Between 1990 and 2015, total emissions show a decrease of about 17%. Among the most significant changes, *non industrial combustion plants*, prevalently *residential plants*, account for 74% of the total in 2015 and show a strong increase (about 90%) due to the increase in wood consumption for heating.

Emissions from *production processes*, mainly *processes in iron* and *steel industries*, account for 10% of the total and show a decrease of 82% 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 8% of the total and show an increase of 12%. Emissions from *combustion in energy and transformation industries*, which are driven by the combustion in iron and steel integrated plants, account for 4% of the total and show a decrease of 68%. Emissions from *road transport*, accounting for 3% in 2015, show an increase of about 38%. 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 2015, with values varying from 503 g I Teq to 280 g I Teq. Figure 2.13 and Table 2.13 illustrate the emission trend from 1990 to 2015. Figure 2.13 also illustrates the share of dioxin emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

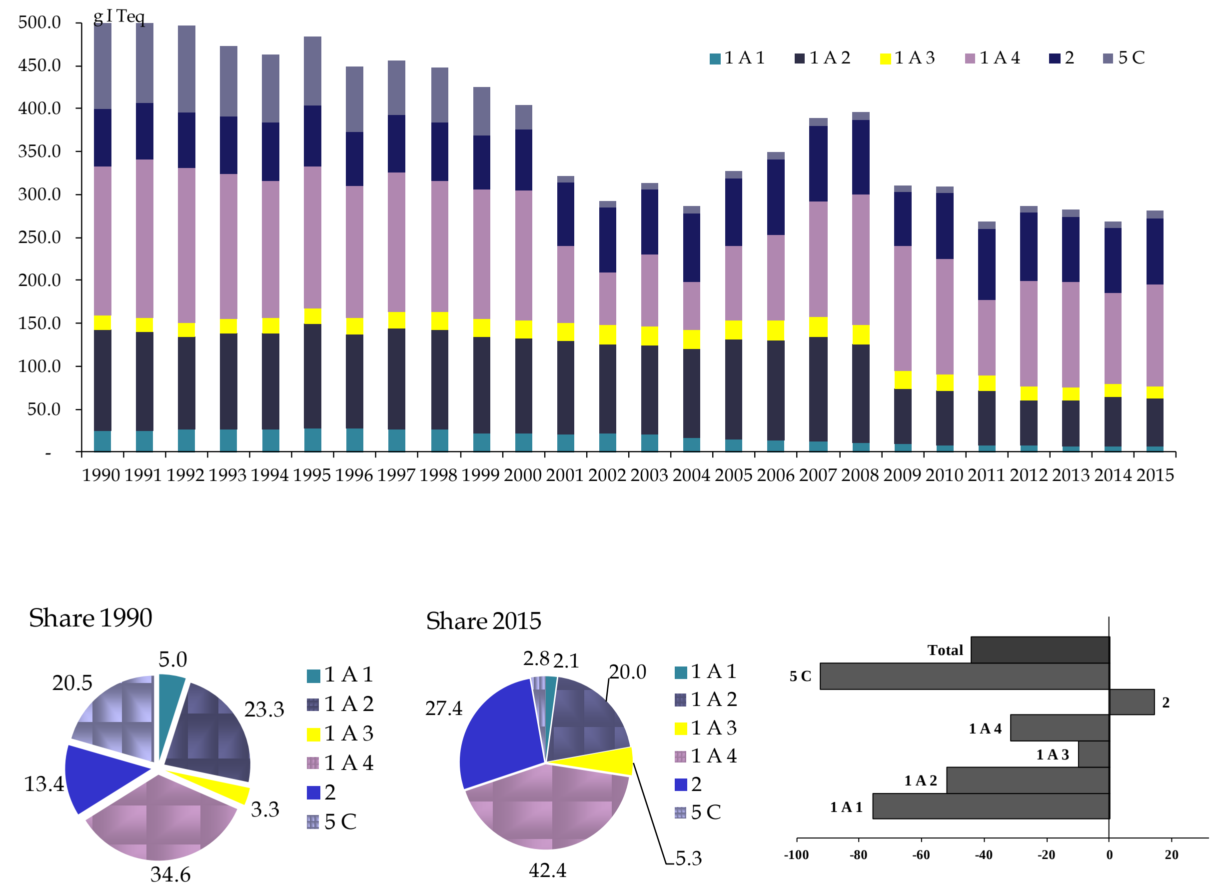

Figure 2.13 *Dioxin emission trend, percentage share by sector and variation 1990-2015*

Table 2.13 *Dioxin emission trend from 1990 to 2015 (g I Teq)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
	g I Teq									
Combustion in energy and transformation industries	25	28	22	15	9	8	8	7	7	6
Non-industrial combustion plants	174	165	151	87	134	87	122	122	106	119
Combustion - industry	117	121	111	116	63	63	52	52	57	56
Production processes	67	72	71	79	76	84	80	77	77	77
Road transport	16	19	21	22	20	19	17	16	16	15
Waste treatment and disposal	103	80	29	8	8	8	8	7	7	8
Total	***503***	***484***	***404***	***327***	***309***	***268***	***287***	***282***	***269***	***280***

The general trend shows a decrease from 1990 to 2015 equal to 44%, with a noticeable decline between 1995 and 2004 and between 2008 and 2010 because of the implementation of abatement system in the largest Italian 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 catalyze the formation of dioxins).

The most considerable reductions, between 1990 and 2015, are observed in *waste treatment and disposal, combustion in energy and transformation industries* and *combustion in industry*, (-92%, -76%and -52%, 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 2015, the subsectors which have contributed most to total emissions are *production processes*, *combustion in industry* and *non-industrial combustion plants* accounting for 27%, 20% and 42% of the total respectively. In particular emissions from production processes show an increase of 14% in the period 1990-2015 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 1990-2015, varying from 43 kg to 20 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 2015. Figure 2.14 also illustrates the share of HCB emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

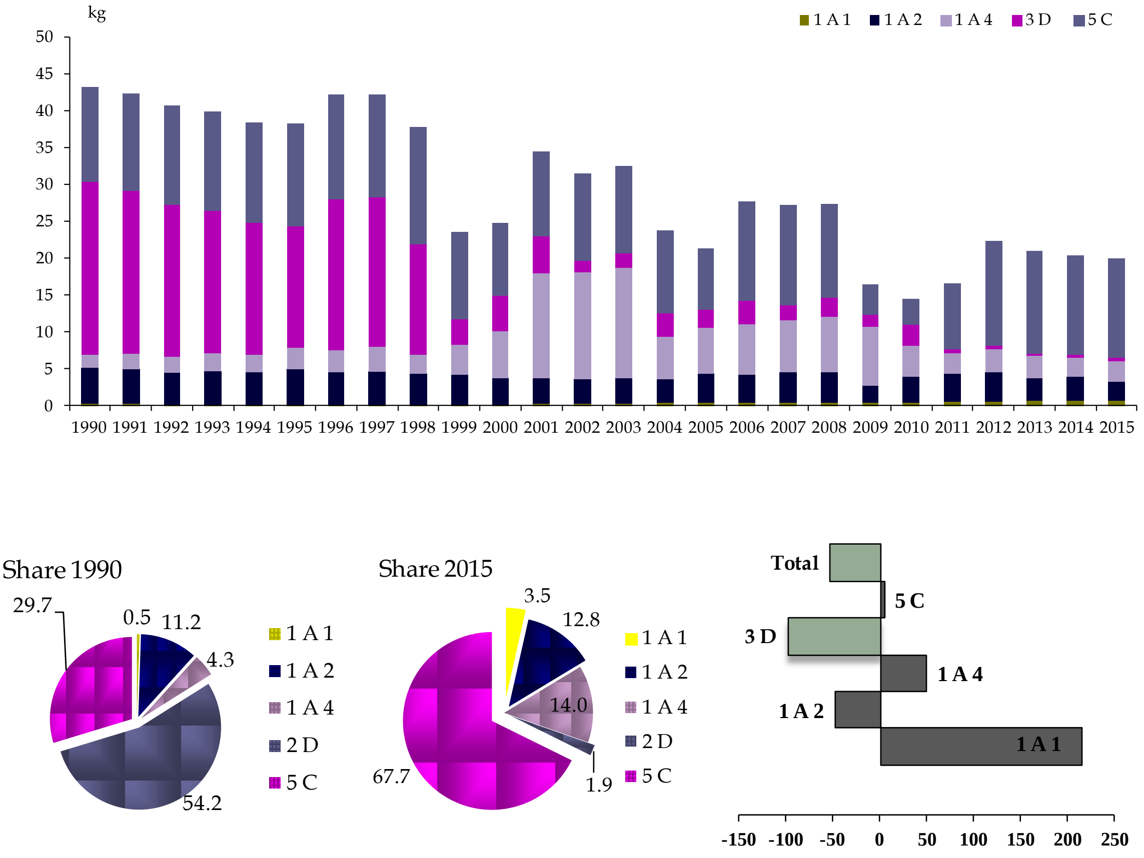

Figure 2.14 *HCB emission trend, percentage share by sector and variation 1990-2015*

Table 2.14 *HCB emission trend from 1990 to 2015 (Mg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					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	0.003	0.003	0.003
Combustion - industry	0.005	0.005	0.004	0.004	0.003	0.004	0.004	0.003	0.003	0.003
Waste treatment and disposal	0.013	0.014	0.010	0.008	0.003	0.009	0.014	0.014	0.014	0.013
Agriculture	0.023	0.016	0.005	0.002	0.003	0.001	0.000	0.000	0.000	0.000
Total	***0.043***	***0.038***	***0.025***	***0.021***	***0.014***	***0.017***	***0.022***	***0.021***	***0.020***	***0.020***

The sector contributing most 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) and in 2012-2015 (incineration without energy recovery). The other relevant sectors are *combustion in industry* and *non industrial combustion plants* accounting for 13% and 14% respectively. Emissions from combustion in energy *and transformation industry* and emissions from *non industrial combustion plants* show an increase of 214% and 49% respectively between 1990 and 2015. In the same years for emissions from *waste treatment and disposal* an increase of 5% has to be noted while emissions from combustion in industry show a decrease of 47%. 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 2015.

2.4.4 *Polychlorinated biphenyl (PCB)*

The national atmospheric emissions of polychlorinated biphenyl show a decreasing trend in the period 1990-2015, about -33%, from 289 kg to 195 kg.

Figure 2.15 and Table 2.15 illustrate the emission trend from 1990 to 2015. Figure 2.15 also illustrates the share of PCB emissions by category in 1990 and 2015 as well as the total and sectoral variation from 1990 to 2015.

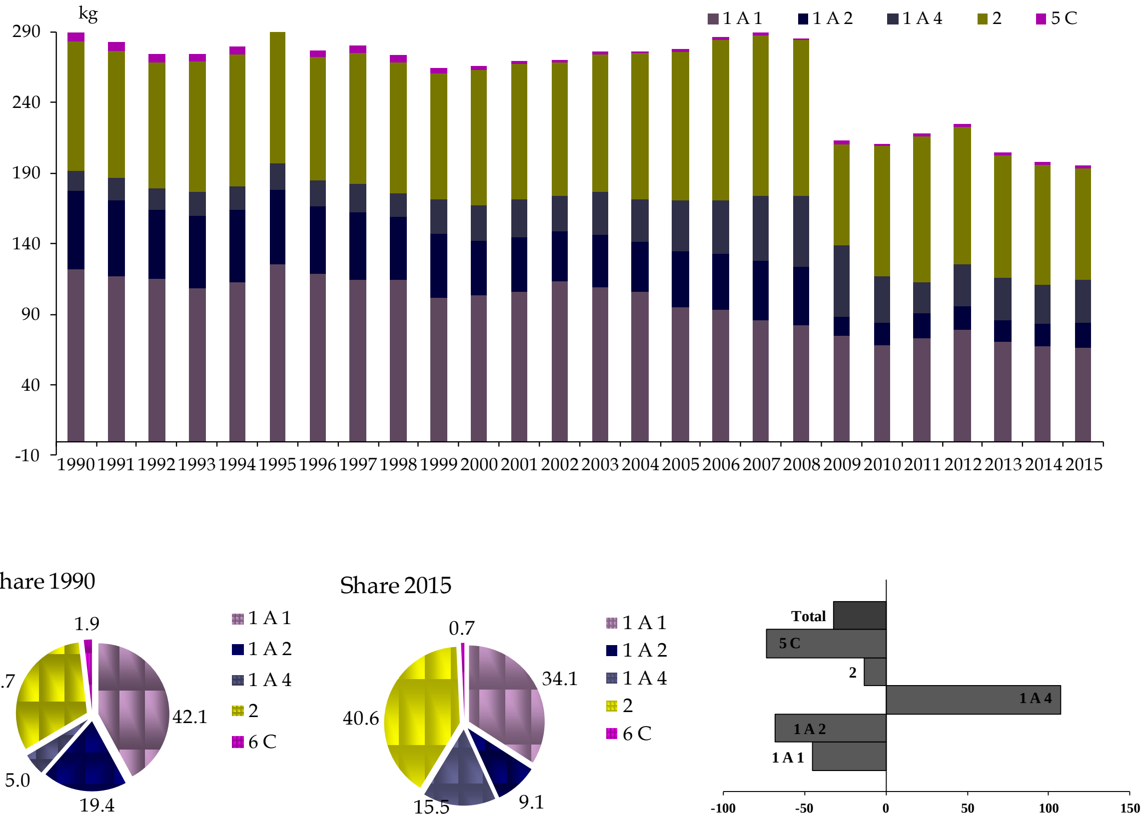

Figure 2.15 *PCB emission trend, percentage share by sector and variation 1990-2015*

Table 2.15 *PCB emission trend from 1990 to 2015 (Mg)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Mg					
Combustion in energy and transformation industries	0.122	0.126	0.103	0.095	0.069	0.073	0.079	0.071	0.068	0.067
Non-industrial combustion plants	0.015	0.018	0.025	0.036	0.033	0.023	0.029	0.030	0.028	0.030
Combustion - industry	0.056	0.053	0.039	0.040	0.016	0.018	0.017	0.015	0.015	0.018
Production processes	0.092	0.100	0.096	0.106	0.093	0.103	0.098	0.087	0.085	0.079
Waste treatment and disposal	0.005	0.005	0.002	0.002	0.001	0.001	0.002	0.002	0.001	0.001
Total	**0.289**	**0.301**	**0.266**	**0.278**	**0.211**	**0.218**	**0.225**	**0.204**	**0.198**	**0.195**

The subsectors contributing most to the general trend are the *production processes* sector and the *combustion in energy and transformation industries* sector, accounting for 41% and 34% of the total emissions respectively, the former showing a decrease of 14%, the latter a reduction of 45%. The other relevant subsectors are *non industrial combustion plants* accounting for 15% and relevantly increasing (107%) and *combustion in industry* which accounts for 9% and decreases between 1990 and 2015 by 68%.

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 (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;
- Commercial;
- Public Service;
- Fishing and Agriculture.

Fugitive emissions are also reported under the energy sector.

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 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 methodology:

- auto-generators are reported in the relevant industrial sectors of section "1.A.2 Manufacturing Industries and Construction", including sector "1.A.2.f Other";
- refineries auto-generation is included in section 1.A.1.b;
- iron and steel auto-generation is included in section 1.A.1.c.

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.4 a i (Combustion activity, commercial/institutional sector), whereas emissions from other types of waste incineration facilities are reported under category 5.C (Waste incineration). In fact, energy recovered by these plants is mainly used for district heating of commercial buildings. In particular, for 2015, more than 98% of the total amount of waste incinerated is treated in plants with energy recovery system. 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 a factor equal to 9.2 GJ/t of waste.

Emissions from landfill gas recovered are used for heating and power in commercial facilities and 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. In consideration of the increasing of the share of waste used to produce electricity, we plan to revise the allocation of these emissions under category 1.A.1.a.

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.

The energy sector account in 2015 for more than 50% of total emissions for all the pollutants estimated, except for HCB which accounts for 30.4% and ammonia for 2.2%. In particular, emissions from the energy sector are 96% of NO_X, 95% of CO and BC, 91% PM2.5 and 90% of SO_X national total emissions.

In 2015, the following categories are key categories for different pollutants: *public electricity and heat production* (1A1a), *petroleum refining* (1A1b), *stationary combustion in manufacturing 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), and *fugitive emissions from refining and storage* (1B2a iv).

The same categories are key categories for 1990 and for the trend analysis. In addition, for 1990, *fugitive emissions from distribution of oil products* (1B2a v) for NMVOC, *manufacture of solid fuels and other energy industries* (1A1c) for PAH emissions, and *mobile combustion in manufacturing industries and construction* (1A2g vii) for BC are also key categories while for trend *mobile combustion in manufacturing industries and construction* (1A2g vii) is also key category.

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 4 programme, version 11.4, has been used to calculate emissions (EMISIA SA, 2016); 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, 2017[a]). At national level, trends of the CLRTAP pollutants are described in the environmental data yearbook published by ISPRA (ISPRA, 2016).

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.

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 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/ .

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 are over 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 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 come back to the 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 estimates emissions at plant level and compare them with those submitted in the EPRTR and LCP. Also in this case we ask for clarification to the plant.

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 2015 the sector accounts for:

- 96% in national total NO_X emissions;
- 95% in national total BC emissions;
- 95% in national total CO emissions;
- 91% in national total PM2.5 emissions;

- 90% in national total SO_X emissions.

Moreover, the sector is also an important source for heavy metals; specifically in 2015, energy sector is responsible for 81% of total Cd emissions and accounts for a high share of other heavy metals, As (99.7%), Cu (95%), Ni (87%), Se (91%).

There are no differences as compared to the sectoral share in 1990, except for lead whose contribution in 1990 was 98% of total emissions, 25% higher than in 2015.

One of the most important source of emissions in the sector, in 2015, is represented by *road transport* (1A3b), at least for the main pollutants: NO_X (51.7%), BC (39.5%), CO (21.0%), NMVOC (17.1%), and particulate matter (PM10 12.2%, PM2.5 11.3%). There has been a strong reduction in lead emissions from 1990 to 2015 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* (1A2f) is a main source of heavy metals and POPs, accounting for about 37% of lead total emissions, 32% for cadmium, 27% for mercury, 20% for dioxin, 13% for HCB and 9% for PCB. The source is key category also for PM10 and PM2.5, (4% both) as well as SO_X, NO_X, and CO about 22%, 8% and 4% of total emissions.

Public electricity and heat production (1A1a) is a key source of SO_X emissions in 2015 with a share of 14.2%, PCB (33.6%) and NO_X emissions (4.8%). A strong reduction of SO_X, NO_X and PM10 emissions is observed for this category (as well as for 1A2f category). 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 for new plants of emissions for PM10, NO_X and SO_X, and required old plants to conform to the limit by 1997, explained the emission reduction in the ninety years. 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 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 collocated in areas with air quality critical values. For this reason plants have increase the use of natural gas heat and power combined technology. In 2015 in Italy there are still 10 coal plants and 4 fuel oil plants 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 a key category for SO_X emissions in 2015 with a share of 8.3%.

National *navigation* (1A3d ii) is key category for SO_X (17.1%), NO_X (9.2%), PM10 (3.1%) and PM2.5 (3.4%). 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 for 16.7% and 25.0% of national total, respectively; CO emissions account for 64.2%; PM10 and PM2.5 emissions account for 64.3% and 71.2% respectively; BC emissions account for 47.6%; dioxin is 42.4%, PAH is 74.4% and HCB is 14.0% of national totals. These emissions are prevalently due to biomass combustion, in winter, and they are also becoming critical for air quality issues. *Non-industrial combustion* is also a key category for heavy metals 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 2015 for SO_X emissions (14.6%). Total SO_X fugitive emissions from distribution of fossil fuels account for 18.0% of the total.

Table 3.1 *Key categories in the energy sector in 2015*

	1A1 a	1A1 b	1A1c	1A2f	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	1A3c	1A3 d ii	1A3e i	1A4 a i	1A4 bi	1A4 bii	1A4c	1A5 b	1B1a	1B1 b	1B2
SO_X	14.2	8.3	1.6	21.8	0.0	0.3	0.1	0.2	0.0	0.1	0.0			0.0	17.1	0.0	3.1	4.8	0.0	0.0	0.1			18.0
NO_X	4.8	1.6	0.3	8.5	1.0	0.6	0.3	20.5	6.7	23.8	0.7			0.1	9.2	0.0	4.5	5.6	0.0	6.7	0.4			0.7
NH_3	0.0			0.2	0.0			1.5	0.0	0.0	0.0			0.0	0.0		0.0	0.4	0.0	0.0	0.0			
NMVOC	0.3	0.1	0.0	0.8	0.2	0.1	0.1	2.9	0.4	0.9	6.1	6.8		0.0	2.0	0.0	3.0	20.5	0.1	1.3	0.1	0.0	0.1	5.3
CO	0.8	0.1	0.9	3.8	0.3	0.1	0.1	11.6	1.1	1.9	6.4			0.0	2.7	0.0	1.1	60.8	0.1	2.3	0.7			0.0
PM10	0.4	0.3	0.0	3.8	0.3	0.0	0.0	3.1	1.6	2.2	0.5		4.8	0.0	3.1	0.0	1.0	61.1	0.0	2.2	0.3	0.3	0.1	0.2
PM2.5	0.4	0.3	0.0	3.5	0.3	0.0	0.0	3.5	1.7	2.5	0.6		2.9	0.0	3.4	0.0	1.1	67.7	0.0	2.5	0.3	0.0	0.0	0.2
BC	0.1	0.1	0.1	1.0	1.2	0.1	0.0	18.7	9.3	10.7	0.7			0.1	3.9	0.0	0.6	38.7	0.0	8.3	1.1	0.2	0.1	0.2
Pb	0.9	0.1	0.0	37.5		0.2	0.1						4.3		0.0		26.5	3.9		0.0	0.0		0.2	
Cd	1.3	0.3	0.0	32.0	0.0	0.0	0.0	3.1	0.6	1.0	0.1		0.8	0.0	0.2		34.0	7.2	0.0	0.3	0.0		1.6	
Hg	7.0	1.2	0.1	26.7													28.1	3.0		0.2			0.7	
PAH	0.4	0.0	3.1	0.6	0.0	0.0	0.0	2.0	0.4	0.6	0.0			0.0	0.1		2.1	71.7	0.0	0.6	0.0			
Dioxin	1.1	1.0		20.0				3.6	0.8	0.7	0.2						1.0	41.2		0.2				
HCB	3.5			12.8													6.0	7.9		0.0				
PCB	33.6	0.5		9.1													7.3	8.1		0.0				

Note: key categories are shaded in blue

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, 2017[b]).

The analysis of data collected from point sources allowed to distribute emissions at local level, for 2010 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 2010. 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 2005 (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 level and figures are compared with 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 2010 is reported in Figure 3.3 whereas methodologies are described in the relevant publication (ISPRA, 2009).

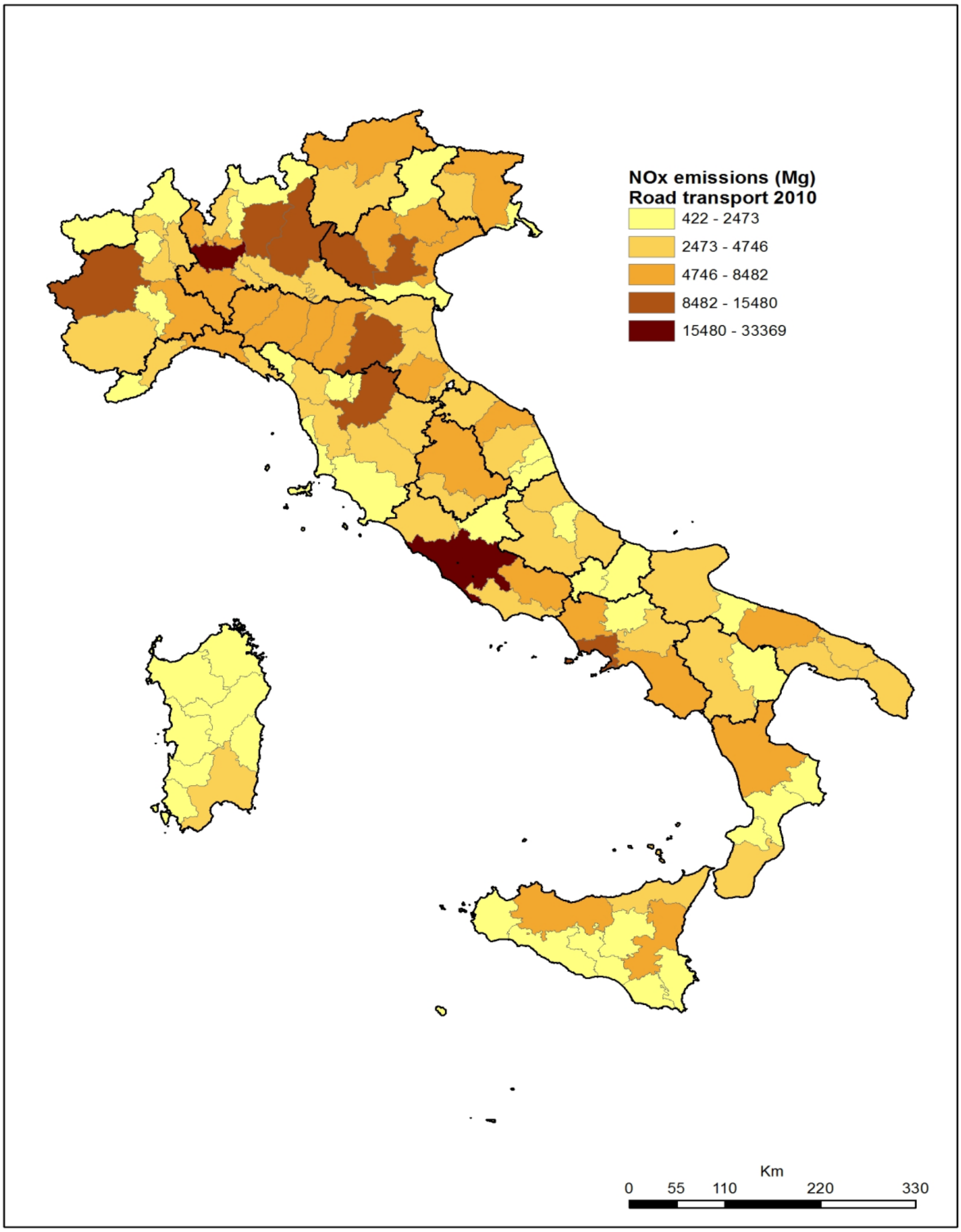

Figure 3.3 *NO_X emissions from road transport in 2010 (t)*

3.5 Recalculations

In the 2017 submission different recalculations have been performed in the energy sector. The main update regarded 1.A.3 and 1.A.4 categories. The complete time series, from 1990 to 2014, of liquid and solid fuel consumptions, for road transport (1.A.3.b), off-road vehicles (1.A.3.c, 1.A.3.d, 1.A.4.b ii, 1.A.4.c) and heating system categories for stationary combustion (1.A.4.a i and 1.A.4.b i), have been updated on the basis of figures submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT.

Moreover, emission reduction targets established in the 2004/26/EC Directive have been applied affecting emission estimates of railway category (1.A.3.c), recreational craft activities (1.A.3.d), household and gardening mobile machinery (1.A.4.b ii), off-road in agriculture, forestry and fishing (1.A.4.c ii and 1.A.4.c iii), and off-road machinery in industry (1.A.2.g vii). More detailed information is reported in the relevant paragraphs.

For road transport (1.A.3.b), the upgraded version of COPERT 4, v.11.4 has been used resulting in a general revision of emission estimates for the whole time series. More detailed results are reported in paragraph 3.8.

In addition, for the category 1.A.4, emissions have been recalculated from 2011 to 2013 taking in account the update of waste fuel consumption for commercial heating and NO_X emission factor for natural gas for 2013 and 2014. More detailed information is reported in paragraph 3.12.

Concerning the aviation category (1.A.3.a), an overall assessment and comparison with emission estimates provided for Italy by Eurocontrol lead to the update of both activity data, from 2002, and NO_X, SO_X, CO, and PM emission factors from 2005, and a consequent recalculation of emissions from this category. More detailed information is reported in paragraph 3.7.

3.6 Planned improvements

Specific improvements are detailed in the 2017 QA/QC plan (ISPRA, 2017[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.

Further progress will regard the maritime sector improving the annual estimations on the basis of detailed databases on ships movements while for the aviation sector further checks are needed for that regard NMVOC and CH_4 emission estimates provided by EUROCONTROL before to implement the relevant changes in the national inventory.

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, as zinc, where figures reported in the EPRTR lead to average values significantly different from those actually used.

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, 2016), 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 2002–2015 (EUROCONTROL, 2016).

An overall assessment and comparison with EUROCONTROL emission estimates was carried out this year which 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, 2016).

EUROCONTROL fuel and emissions time series cover the period 2005-2015, while the number of flights are available since 2002. In this year submission, EUROCONTROL data, related to Italy, on the number of flights have been used to update the national inventory from 2002, while fuel and emissions data have been used since 2005, with the exception of HC emissions (both NMVOC and CH_4) and cruise emissions of CO, for which the previous methodology has been kept, because of the need to further investigate on the discrepancies with previous estimates.

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 1999considering 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 with the exception of HC emissions (both NMVOC and CH4) and cruise CO emissions, for which further assessment is needed. For these last pollutants, emission factors were derived from the results of a second national survey conducted for the years 2005-2007 (TECHNE, 2009). 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, 2016).

In general, to carry out national estimates of greenhouse gases and other pollutants in the Italian inventory 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 Economical 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 2015 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.

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.

Table 3.2 *Aircraft Movement Data (LTO cycles)*

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Domestic flights	186,446	199,585	319,963	350,092	354,515	354,016	327,121	294,398	291,099	280,641
International flights	139,733	184,233	303,747	381,192	406,981	417,076	410,300	400,844	410,815	425,404

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	2011	2012	2013	2014	2015
					Gg					
Domestic LTO	121	129	208	207	212	197	184	164	172	160
International LTO	123	162	258	257	282	271	271	267	294	310
Domestic cruise	387	414	654	590	652	644	591	537	531	497
International cruise	1215	1662	2296	2569	2615	2746	2637	2616	2637	2800

Source: ISPRA elaborations

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 2015 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 flights in the last years. 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	2011	2012	2013	2014	2015
1 A 3 a ii (i) Domestic aviation LTO (civil)	1.36	1.47	2.50	2.55	2.72	2.67	2.50	2.23	2.23	2.13
1 A 3 a i (i) International aviation LTO (civil)	1.60	2.16	3.21	3.49	4.03	4.07	4.07	4.04	4.32	4.60
1 A 3 a Civil Aviation (LTO)	**2.97**	**3.62**	**5.70**	**6.04**	**6.74**	**6.73**	**6.58**	**6.27**	**6.55**	**6.72**
1A3 a ii (ii) Domestic aviation cruise (civil)	5.28	5.66	9.45	8.59	10.14	10.04	9.31	8.43	8.34	7.99
1A3a i (ii) International aviation cruise (civil)	18.85	26.83	38.68	34.25	38.11	39.07	38.50	38.27	40.67	43.27
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**11.16**	**11.99**	**7.24**	**13.50**	**6.11**	**4.68**	**3.93**	**6.01**	**4.35**	**3.29**

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	2011	2012	2013	2014	2015
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.24	0.26	0.54	1.03	0.60	0.60	0.56	0.50	0.49	0.48
1 A 3 a i (i) International aviation LTO (civil)	0.44	0.60	0.97	1.60	1.12	1.15	1.13	1.11	1.13	1.17
1 A 3 a Civil Aviation (LTO)	**0.69**	**0.86**	**1.51**	**2.64**	**1.72**	**1.75**	**1.69**	**1.61**	**1.63**	**1.65**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.37	0.29	0.50	0.56	0.65	0.42	0.44	0.28	0.28	0.28
1A3a i (ii) International aviation cruise (civil)	0.68	0.97	1.37	1.06	1.05	1.07	1.05	1.03	1.06	1.09
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**3.00**	**3.13**	**1.90**	**3.00**	**1.05**	**0.81**	**0.62**	**1.00**	**0.84**	**0.66**

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	2011	2012	2013	2014	2015
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.11	0.12	0.21	0.23	0.23	0.21	0.19	0.17	0.18	0.17
1 A 3 a i (i) International aviation LTO (civil)	0.13	0.17	0.26	0.27	0.30	0.29	0.29	0.28	0.31	0.33
1 A 3 a Civil Aviation (LTO)	**0.24**	**0.29**	**0.47**	**0.50**	**0.52**	**0.50**	**0.48**	**0.45**	**0.49**	**0.50**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.37	0.39	0.66	0.68	0.72	0.69	0.63	0.56	0.56	0.53
1A3a i (ii) International aviation cruise (civil)	1.25	1.78	2.58	2.37	2.54	2.59	2.54	2.52	2.66	2.81
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**1.19**	**0.81**	**0.21**	**0.17**	**0.13**	**0.11**	**0.04**	**0.10**	**0.14**	**0.12**

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	2011	2012	2013	2014	2015
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
1 A 3 a i (i) International aviation LTO (civil)	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
1 A 3 a Civil Aviation (LTO)	**0.02**	**0.03**	**0.05**	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.08	0.08	0.13	0.10	0.09	0.09	0.09	0.07	0.07	0.07
1A3a i (ii) International aviation cruise (civil)	0.26	0.38	0.54	0.50	0.40	0.41	0.39	0.38	0.40	0.41
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**1.30**	**1.57**	**0.91**	**1.63**	**0.83**	**0.64**	**0.50**	**0.79**	**0.63**	**0.48**

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	2011	2012	2013	2014	2015
1 A 3 a ii (i) Domestic aviation LTO (civil)	1.23	1.33	2.25	2.25	2.28	1.88	1.82	1.64	1.90	1.70
1 A 3 a i (i) International aviation LTO (civil)	1.72	2.31	3.31	2.79	2.92	2.57	2.54	2.51	3.02	3.21
1 A 3 a Civil Aviation (LTO)	**2.95**	**3.63**	**5.56**	**5.04**	**5.20**	**4.45**	**4.36**	**4.15**	**4.92**	**4.91**
1A3 a ii (ii) Domestic aviation cruise (civil)	13.78	7.82	14.27	17.96	23.97	9.57	11.88	3.38	3.42	3.90
1A3a i (ii) International aviation cruise (civil)	1.56	2.21	3.16	2.77	2.93	3.00	2.95	2.88	2.95	3.06
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**65.12**	**79.02**	**45.49**	**54.48**	**17.33**	**14.12**	**6.32**	**13.90**	**19.55**	**16.49**

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	2011	2012	2013	2014	2015
1 A 3 a ii (i) Domestic aviation LTO (civil)	0.19	0.20	0.35	0.38	0.38	0.38	0.35	0.32	0.31	0.30
1 A 3 a i (i) International aviation LTO (civil)	0.21	0.28	0.43	0.54	0.57	0.59	0.58	0.56	0.58	0.60
1 A 3 a Civil Aviation (LTO)	**0.39**	**0.48**	**0.77**	**0.91**	**0.96**	**0.97**	**0.93**	**0.88**	**0.89**	**0.90**
1A3 a ii (ii) Domestic aviation cruise (civil)	0.57	0.62	1.06	1.16	1.18	1.18	1.09	0.98	0.97	0.93
1A3a i (ii) International aviation cruise (civil)	2.01	2.86	4.36	5.48	5.85	5.99	5.89	5.76	5.90	6.11
1 A 5 b Other, Mobile (including military, land based and recreational boats)	**16.34**	**4.22**	**1.16**	**0.001**	**NA**	**0.002**	**0.002**	**0.06**	**0.06**	**0.12**

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 offlights have been compared considering different sources: ENAC, ASSAEROPORTI, ISTAT, EUROCONTROL and verification activities have been performed on the basis of the updated EUROCONTROL data onfuel 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, on the basis of the integration in the Italian inventory of EUROCONTROL data time series, resulting in variations of the number of flights, consumption and emission factors, with respect to previous submission.

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 ISTAT information.

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 2015 as follows: nitrogen oxides emissions for 51.7% of the total; emissions of carbon monoxide for 21.0%, non-methane volatile organic compounds for 17.1%, PM10 and PM2.5, for 12.2% and 11.3%, 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 vehicle tyre and brake wear

Emissions from road surface wear (code: 1.A.3.b.vii) are at present not estimated. Although emission factors are available on the EMEP/EEA Guidebook they have been not included in the COPERT model because considered not sufficiently reliable.

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, 2016).

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: http://www.emisia.com/copert/).

The updated version 11.4 of the model COPERT 4 (EMISIA SA, 2016) has been used for the whole time series (except for natural gas passenger cars detailed categories, differentiated for technology and for engine capacity classes <1.4 l, 1.4 2 l, >2 l, for which a customized database has been used to correctly reproduce the features of the Italian fleet).

COPERT 4 version 11.4 introduces the following upgrades respect to the previous version 11.3 used (http://emisia.com/products/copert/versions):

- New PC Euro 6 2020+ and LDV Euro 6 2021+ vehicle category;
- Updated NOx emission factors for PC Diesel & LDV Diesel, Euro6 and on;
- PC Diesel post Euro 6;
- LDV Diesel post Euro 5.

The model, on the basis of the inputs inserted, gives output results separately for vehicles category and urban, rural, highway areas, concerning emission estimates of CO, VOC, NMVOC, CH_4, NO_X, N_2O, NH_3, $PM_{2.5}$, PM_{10}, 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 national energy balance (MSE, several years); in 2017 consumption data have been updated according to EUROSTAT energy balance, published on the MSE website (http://dgsaie.mise.gov.it/dgerm/ben.asp).
Time series of consumptions, by fuel and vehicle categories, are detailed in the NFR.

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 2016 (EMEP/EEA, 2016).

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 4. 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 4 (EMISIA SA, 2016). 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 aftertreatments are used, EC and OM does not add up to 100%, assuming that the remaining fraction consists of ash, nitrates, sulphates, water and ammonium salts (EMEP/EEA 2016).

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 1990-2015 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 4, version 11.4. 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 in 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).

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.

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, 2016).

3.8.2.3 Emissions from tyre and brake wear

Not exhaust PM emissions from road vehicle tyre and brake wear are estimated (road wear is at present not included in the estimation model). 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, 2016).

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 on the basis of National Association of Cycle-Motorcycle Accessories data on mopeds fleet composition and mileages (ANCMA, several years). ANCMA data have been used up to 2011; since 2012 MIT mopeds fleet data have been used, because starting from 2012, mopeds are estimated to be all registered.

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 (the categories of “E85” and “Hybrid Gasoline” 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 and CNG for 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)) and from the statistics published by the Association of Oil Companies (UP, several years). 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, related to E85 passenger cars category, 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;
- E85 passenger cars;
- Hybrid Gasoline 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;
- 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	2011	2012	2013	2014	2015
Gasoline Leaded	12280212	10112250	4542113	0	0	0	0	0	0	0
Gasoline Unleaded	639115	7060391	12175814	13482132	9806890	9467995	8377986	8014000	8103811	7809940
Diesel	15278022	14445441	17059010	22327864	21557266	21806853	20768959	20255549	21704506	21128587
LPG	1342000	1478000	1422000	1029000	1214000	1267000	1350000	1537000	1564000	1654000
CNG	182656	215573	293799	341876	610015	629433	664107	710151	757400	786518
Biodiesel	0	44491	64723	173709	1275023	1264601	1241150	1156033	1037042	1122160
Bioethanol	0	0	0	0	142106	132750	123428	87178	12039	30420

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.

Fuel information has been updated also as regards country specific fuel consumption factors for gasoline and diesel passenger cars on the basis of the results published by the European Environmental Agency in the report “Monitoring CO_2 emissions from new passenger cars and vans in 2015” (EEA, several years).

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).

In COPERT a simulation process is started up having the target to equalize calculated and statistical consumptions, separately for fuel (gasoline including bioethanol, diesel including biodiesel, LPG and CNG) 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) and a percentage deviation is calculated.

On the basis of the obtained deviation value, a process of refinement of the estimates is performed by acting on control variables such as speeds and mileages. These variables values are changed according to the constraints on the national average variability ranges (identified on the basis of the official data and information on the fleet peculiarities, described in this chapter). As a result of sequential refinements on input data in the detail of vehicle category legislation standard, the estimation process is repeated until the achievement of the deviation value 0.00% as minimum target, assumed as goodness of fit to the “true” BEN statistical value.

The results of the fuel balance process for the year 2015 in Italy, obtained from the application of the model COPERT 4, are shown in the following table 3.11.

Table 3.11 *Fuel balance results for Italy, year 2015*

Fuel	Statistical (t)	Calculated (t)	Deviation (%)
Gasoline (fossil & bio)	7,840,360.00	7,840,360.64	0.0000%
Diesel (fossil & bio)	22,250,746.62	22,250,740.63	0.0000%
LPG	1,654,000.00	1,654,000.30	0.0000%
CNG	786,518.00	786,518.38	0.0000%

Source: ISPRA elaborations by Copert model

In the following Tables 3.12, 3.13, 3.14 and 3.15 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 3.12 *Passenger Cars technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
PRE ECE, pre-1973	0.05	0.03	0.01	0.01	0.002	0.002	0.003	0.002	0.002	0.002
ECE 15/00-01, 1973-1978	0.11	0.04	0.01	0.004	0.003	0.003	0.003	0.003	0.003	0.003
ECE 15/02-03, 1978-1984	0.32	0.15	0.03	0.01	0.01	0.008	0.009	0.008	0.007	0.007
ECE 15/04, 1985-1992	0.53	0.56	0.28	0.10	0.04	0.03	0.03	0.03	0.03	0.03
PC Euro 1 - 91/441/EEC, from 1/1/93	0.001	0.23	0.27	0.17	0.05	0.04	0.03	0.03	0.02	0.02
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.39	0.32	0.22	0.19	0.15	0.15	0.13	0.12
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.31	0.19	0.18	0.18	0.14	0.13	0.13
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.09	0.44	0.43	0.45	0.45	0.43	0.43
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.04	0.11	0.14	0.19	0.23	0.21
PC Euro 6 - EC 715/2007, from 9/1/2015	-	-	-	-	-	0.0000001	0.0003	0.003	0.02	0.06
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	2011	2012	2013	2014	2015
Conventional, pre-1993	1.00	0.92	0.34	0.06	0.01	0.01	0.01	0.01	0.00	0.00
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.08	0.10	0.03	0.01	0.01	0.01	0.00	0.00	0.00
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.56	0.22	0.05	0.03	0.03	0.03	0.03	0.02
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.56	0.31	0.25	0.23	0.21	0.20	0.18
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.12	0.55	0.53	0.51	0.48	0.44	0.42
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.07	0.17	0.22	0.27	0.32	0.33
PC Euro 6 - EC 715/2007, from 9/1/2015	-	-	-	-	0.0001	0.0003	0.0007	0.002	0.009	0.040
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	2011	2012	2013	2014	2015
Conventional, pre-1993	1.00	0.90	0.71	0.47	0.04	0.03	0.02	0.02	0.02	0.01
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.10	0.20	0.26	0.03	0.03	0.02	0.02	0.01	0.01
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.09	0.19	0.08	0.11	0.08	0.07	0.04	0.03
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.06	0.08	0.10	0.07	0.07	0.05	0.05
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.01	0.75	0.66	0.60	0.55	0.51	0.45
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.03	0.07	0.20	0.28	0.35	0.36
PC Euro 6 - EC 715/2007, from 9/1/2015	-	-	-	-	-	-	0.0001	0.0007	0.03	0.08
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	2011	2012	2013	2014	2015
Conventional, pre-1993	1.00	0.89	0.54	0.24	0.01	0.01	0.01	0.01	0.01	0.01
PC Euro 1 - 91/441/EEC, from 1/1/93	-	0.11	0.24	0.22	0.02	0.02	0.01	0.01	0.01	0.01
PC Euro 2 - 94/12/EEC, from 1/1/97	-	-	0.22	0.27	0.15	0.10	0.08	0.07	0.04	0.03
PC Euro 3 - 98/69/EC Stage2000, from 1/1/2001	-	-	-	0.21	0.12	0.12	0.12	0.08	0.08	0.06
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	-	-	-	0.06	0.59	0.59	0.54	0.51	0.46	0.41
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	-	-	0.10	0.16	0.23	0.32	0.37	0.37
PC Euro 6 - EC 715/2007, from 9/1/2015	-	-	-	-	-	-	0.00001	0.0001	0.04	0.11
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

	2008	2009	2010	2011	2012	2013	2014	2015
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	1.00	1.00	0.88	0.68	0.54	0.54	0.52	0.53
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	0.12	0.32	0.46	0.46	0.47	0.47
PC Euro 6 - EC 715/2007, from 9/1/2015	-	-	-	-	-	-	0.00	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

e. E85 cars technological evolution (from 2008 onwards)

	2007	2008	2009	2010	2011	2012	2013	2014	2015
PC Euro 4 - 98/69/EC Stage2005, from 1/1/2006	1.00	1.00	0.65	0.54	0.43	0.35	0.23	0.15	0.22
PC Euro 5 - EC 715/2007, from 1/1/2011	-	-	0.35	0.46	0.57	0.64	0.77	0.77	0.61
PC Euro 6 - EC 715/2007, from 9/1/2015	-	-	-	-	-	0.01	0.001	0.08	0.16
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

f. Hybrid Gasoline cars technological evolution (from 2007 onwards)

Source: ISPRA elaborations on MIT and ACI data

Table 3.13 *Light Duty Vehicles technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Conventional, pre 10/1/94	1.00	0.93	0.63	0.35	0.08	0.07	0.07	0.05	0.05	0.05
LD Euro 1 - 93/59/EEC, from 10/1/94	-	0.07	0.22	0.17	0.11	0.08	0.08	0.06	0.06	0.05
LD Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.15	0.15	0.30	0.23	0.22	0.22	0.21	0.20
LD Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.31	0.26	0.23	0.22	0.20	0.20	0.19
LD Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.25	0.30	0.29	0.31	0.30	0.31
LD Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.004	0.10	0.13	0.16	0.18	0.19
LD Euro 6	-	-	-	-	-	-	-	0.00	0.005	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

a. Gasoline Light Duty Vehicles technological evolution

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Conventional, pre 10/1/94	1.00	0.93	0.60	0.28	0.08	0.08	0.04	0.02	0.02	0.02
LD Euro 1 - 93/59/EEC, from 10/1/94	-	0.07	0.21	0.13	0.07	0.07	0.05	0.05	0.05	0.04
LD Euro 2 - 96/69/EEC, from 10/1/98	-	-	0.19	0.18	0.23	0.21	0.19	0.15	0.14	0.14
LD Euro 3 - 98/69/EC Stage2000, from 1/1/2002	-	-	-	0.39	0.33	0.32	0.33	0.33	0.33	0.23
LD Euro 4 - 98/69/EC Stage2005, from 1/1/2007	-	-	-	0.01	0.28	0.29	0.32	0.34	0.32	0.35
LD Euro 5 - 2008 Standards 715/2007/EC, from 1/1/2012	-	-	-	-	0.01	0.03	0.06	0.11	0.15	0.21
LD Euro 6	-	-	-	-	0.0000003	0.0000003	0.000007	0.00003	0.0003	0.005
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

b. Diesel Light Duty Vehicles technological evolution

Source: ISPRA elaborations on MIT and ACI data

Table 3.14 *Heavy Duty Trucks and Buses technological evolution: circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Conventional, pre 10/1/93	1.00	0.90	0.68	0.40	0.19	0.18	0.16	0.12	0.12	0.11
HD Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.10	0.10	0.06	0.05	0.05	0.05	0.05	0.04	0.04
HD Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.22	0.27	0.22	0.21	0.20	0.20	0.19	0.18
HD Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.27	0.34	0.33	0.33	0.33	0.33	0.32
HD Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.06	0.06	0.06	0.06	0.06	0.06
HD Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.14	0.17	0.20	0.23	0.24	0.24
HD Euro VI – EC 595/2009, from	-	-	-	-	-	-	0.00002	0.002	0.02	0.04

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
12/31/2013										
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	2011	2012	2013	2014	2015
Conventional, pre 10/1/93	1.00	0.93	0.65	0.34	0.16	0.14	0.08	0.07	0.06	0.06
HD Euro I - 91/542/EEC Stage I, from 10/1/93	-	0.07	0.07	0.08	0.06	0.05	0.05	0.05	0.05	0.04
HD Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.28	0.32	0.29	0.28	0.28	0.27	0.25	0.24
HD Euro III - 2000 Standards, 99/96/EC, from 10/1/2001	-	-	-	0.26	0.30	0.30	0.31	0.31	0.30	0.30
HD Euro IV - 2005 Standards, 99/96/EC, from 10/1/2006	-	-	-	-	0.10	0.10	0.10	0.10	0.10	0.10
HD Euro V - 2008 Standards, 99/96/EC, from 10/1/2009	-	-	-	-	0.09	0.13	0.17	0.20	0.22	0.22
HD Euro VI – EC 595/2009, from 12/31/2013	-	-	-	-	-	-	0.0001	0.0009	0.01	0.04
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	2011	2012	2013	2014	2015
Urban CNG Buses Euro I - 91/542/EEC Stage I, from 10/1/93	1.00	1.00	0.11	0.01	0.003	0.001	0.000	0.003	0.002	0.003
Urban CNG Buses Euro II - 91/542/EEC Stage II, from 10/1/96	-	-	0.89	0.20	0.10	0.08	0.07	0.07	0.06	0.05
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	0.08	0.08	0.08	0.07	0.07
Euro V - 2008 Standards, 99/96/EC, from 10/1/2009; EEV (Enhanced environmentally friendly vehicle; ref. 2001/27/EC and 1999/96/EC line C, optional limit emission values)	-	-	-	-	0.81	0.84	0.85	0.85	0.87	0.88
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

Source: ISPRA elaborations on MIT and ACI data

Table 3.15 *Mopeds and motorcycles technological evolution***:** *circulating fleet calculated as stock data multiplied by actual mileage (%)*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Conventional, pre 6/17/1999	1.00	1.00	0.86	0.46	0.22	0.19	0.17	0.16	0.15	0.12
Euro I, 97/24/EC, from 6/17/1999	-	-	0.14	0.28	0.17	0.15	0.14	0.13	0.12	0.11
Euro II, 2002/51/EC, 2003/77/EC, from 7/1/2004 (for mopeds: 97/24/EC, from 6/17/2002)	-	-	-	0.21	0.34	0.35	0.34	0.33	0.35	0.35
Euro III, 2002/51/EC, 2003/77/EC, from 1/1/2007 (for mopeds not defined yet)	-	-	-	0.04	0.27	0.31	0.35	0.38	0.39	0.41
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 3.16, 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 3.16 *Evolution of fleet consistency and mileage*

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
All passenger vehicles (including moto), total mileage (10^9 veh-km/y)	304	366	392	394	429	425	397	378	366	360	344	349	375	377
Car fleet (10^6)	27	30	33	35	35	36	37	37	38	38	38	38	38	39
Moto, total mileage (10^9 veh-km/y)	31	39	41	42	39	35	37	34	33	34	33	32	33	33
Moto fleet (10^6)	7	7	9	10	10	10	10	10	10	10	9	9	9	10
Goods transport, total mileage (10^9 veh-km/y)	68	75	94	109	97	103	102	101	106	110	100	90	92	81
Truck fleet (10^6), including LDV	2	3	3	4	4	5	5	5	5	5	5	5	5	5

Source: ISPRA elaborations

Notes: The passenger vehicles include passenger cars and buses; 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 economical crisis in recent years, on the other side.

In Table 3.17 the list of key categories by pollutant identified for road transport in 2015, 1990 and at trend assessment is reported.

Table 3.17 *List of key categories for pollutant in the road transport in 2015, 1990 and in the trend*

	Key categories in 2015			*Key categories in 1990*				*Key categories in trend*		
SO_X								1A3bi		
NO_X	1A3bi	1A3bii	1A3biii	1A3bi	1A3biii			1A3bi	1A3bii	1A3biii
NMVOC	1A3bi	1A3biv	1A3bv	1A3bi	1A3biv	1A3bv		1 A 3 bi	1 A 3 bv	
NH_3								1A3bi		
CO	1A3bi	1A3biv		1A3bi	1A3biv			1A3bi		
PM_{10}	1A3bi	1A3biii	1A3bvi	1A3bi	1A3bii	1A3biii	1A3bvi	1 A 3 bi	1 A 3 biii	
$PM_{2.5}$	1A3bi	1A3bvi		1A3bi	1A3bii	1A3biii		1 A 3 bi	1 A 3 biii	
BC	1A3bi	1A3bii	1A3biii	1A3bi	1A3bii	1A3biii		1A3bi	1A3bii	1A3biii
Pb				1A3bi				1A3bi		

Source: ISPRA elaborations

In 2015 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 and black carbon.

Nitrogen oxides emissions show a decrease since 1990 of about 58.2%. Emissions are mainly due to diesel vehicles. The decrease observed since 1990 in emissions relates to all categories except for diesel passenger cars and light duty vehicles, CNG buses, mopeds.

In 2015, emissions of nitrogen oxides (Table 3.18) from passenger cars, light-duty vehicles and heavy-duty trucks including buses are key categories. The same categories are identified as key categories in trend;

in 1990 passenger cars and heavy-duty trucks including buses are key categories while light-duty vehicles are not a key category.

Table 3.18 *Time series of nitrogen oxides emissions in road transport (Gg)*

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
	Gg									
1.A.3.b.i Passenger cars	529.68	591.28	361.91	224.14	156.85	146.85	142.91	144.32	156.13	156.52
1.A.3.b.ii Light-duty vehicles	66.76	70.62	85.75	87.81	75.73	78.43	68.03	59.24	62.12	51.24
1.A.3.b.iii Heavy-duty vehicles including buses	341.35	330.12	302.91	286.56	222.87	221.96	206.44	189.47	184.10	181.32
1.A.3.b.iv Mopeds and motorcycles	5.55	6.69	7.50	6.47	5.15	5.37	5.39	5.15	5.13	5.18
Total emissions	**943.33**	**998.71**	**758.06**	**604.98**	**460.60**	**452.61**	**422.77**	**398.19**	**407.48**	**394.26**

Source: ISPRA elaborations

As regards non methane volatile organic compounds, emissions from passenger cars, mopeds and motorcycles and gasoline evaporation are key categories in 2015 and 1990, while emissions from passenger cars and gasoline evaporation are key categories in trend.

Despite the decline of about 83.3% since 1990 of emissions of non methane volatile organic compounds from this category, road transport (Table 3.19) is the third source at national level after the *use of solvents* and not industrial combustion; 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 9.6 million vehicles in 2015) that uses gasoline and it is increased of about 44.9% since 1990 (this fleet not completely complies with strict VOC emissions controls).

Table 3.19 *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	2011	2012	2013	2014	2015
	Gg									
1.A.3.b.i Passenger cars	477.18	504.82	273.66	116.15	43.56	35.51	30.81	28.44	25.92	24.53
1.A.3.b.ii Light-duty vehicles	17.00	17.43	14.97	11.51	7.70	7.49	6.21	4.78	4.65	3.38
1.A.3.b.iii Heavy-duty vehicles including buses	26.74	24.83	20.12	15.60	9.96	9.89	8.98	7.60	7.34	7.28
1.A.3.b.iv Mopeds and motorcycles	153.85	205.47	190.06	156.63	73.95	69.13	57.34	55.15	55.45	51.05
1.A.3.b.v Gasoline evaporation	184.85	185.98	137.05	79.15	55.90	58.80	60.30	54.52	52.97	57.49
Total emissions	**859.61**	**938.53**	**635.85**	**379.05**	**191.07**	**180.83**	**163.64**	**150.49**	**146.32**	**143.73**

Source: ISPRA elaborations

Carbon monoxide emissions from passenger cars and mopeds and motorcycles are key categories in 2015 and 1990; passenger cars are also key category in trend. The time series of CO emissions is reported in Table 3.20.

Table 3.20 *Time series of carbon monoxide emissions in road transport (Gg)*

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
	Gg									
1.A.3.b.i Passenger cars	4,541.48	4,420.03	2,317.32	1,063.25	456.88	383.34	334.98	306.24	282.88	273.11
1.A.3.b.ii Light-duty vehicles	198.67	200.47	148.90	99.25	55.40	51.18	43.25	34.39	33.55	26.18
1.A.3.b.iii Heavy-duty vehicles including buses	82.98	79.13	68.82	63.06	52.46	53.88	50.99	46.93	45.91	45.80
1.A.3.b.iv Mopeds and	506.03	636.14	613.15	422.90	203.74	196.31	177.79	166.65	162.95	150.22

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
				Gg						
motorcycles										
Total emissions	**5,329.16**	**5,335.77**	**3,148.19**	**1,648.46**	**768.47**	**684.72**	**607.01**	**554.20**	**525.29**	**495.30**

Source: ISPRA elaborations

A strong contribution to total emissions is given by gasoline vehicles (about 76.4% in 2015, although since 1990 a decrease of about 92.3% is observed); since 1990 to 2015 a general decrease, of about 90.7%, is observed.

Emissions of PM_{10} (Table 3.21) 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, heavy-duty vehicles including buses and road vehicle tyre and brake wear are key categories in 2015; emissions from passenger cars and heavy-duty vehicles including buses are key category in trend.

As regards $PM_{2.5}$ (Table 3.22), emissions from passenger cars, light-duty vehicles, heavy-duty vehicles including buses are key categories in 1990; while emissions from passenger cars and road vehicle tyre and brake wear are key categories in 2015 and emissions from passenger cars and heavy-duty vehicles including buses are key category in trend.

Table 3.21 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	2011	2012	2013	2014	2015
					Gg					
1.A.3.b.i Passenger cars	18.65	14.47	10.86	9.43	7.27	6.27	5.79	5.64	5.82	5.53
1.A.3.b.ii Light-duty vehicles	10.03	11.56	13.47	10.76	6.95	6.73	5.11	3.87	3.80	2.77
1.A.3.b.iii Heavy-duty vehicles including buses	13.81	13.18	10.53	8.16	5.34	5.25	4.79	4.20	4.06	3.98
1.A.3.b.iv Mopeds and motorcycles	3.16	4.25	3.97	3.35	1.50	1.40	1.18	1.12	1.08	0.98
1 A 3 b vi Road Transport:, Automobile tyre and brake wear	7.79	8.96	9.40	9.69	9.04	9.08	8.57	8.36	8.79	8.59
Total emissions	**53.45**	**52.43**	**48.24**	**41.39**	**30.10**	**28.74**	**25.44**	**23.20**	**23.55**	**21.86**

Source: ISPRA elaborations

Table 3.22 *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	2011	2012	2013	2014	2015
					Gg					
1.A.3.b.i Passenger cars	18.65	14.47	10.86	9.43	7.27	6.27	5.79	5.64	5.82	5.53
1.A.3.b.ii Light-duty vehicles	10.03	11.56	13.47	10.76	6.95	6.73	5.11	3.87	3.80	2.77
1.A.3.b.iii Heavy-duty vehicles including buses	13.81	13.18	10.53	8.16	5.34	5.25	4.79	4.20	4.06	3.98
1.A.3.b.iv Mopeds and motorcycles	3.16	4.25	3.97	3.35	1.50	1.40	1.18	1.12	1.08	0.98
1 A 3 b vi Road Transport:, Automobile tyre and brake wear	4.20	4.84	5.12	5.30	4.96	4.98	4.69	4.59	4.82	4.71
Total emissions	**49.85**	**48.31**	**43.96**	**36.99**	**26.01**	**24.63**	**21.57**	**19.42**	**19.59**	**17.98**

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 -59.1% and -63.9%; despite the decrease, diesel vehicles (passenger cars, light duty vehicles and heavy duty trucks) are mainly responsible for road transport emissions giving a strong contribution to total emissions, in 2015 about 82.4% and 85.3% out of the total for PM_{10} and $PM_{2.5}$ respectively.

Emissions of black carbon are reported in Table 3.23. Emissions from passenger cars, light-duty vehicles and heavy-duty trucks including buses are key categories in 1990, 2015 and in trend.

The emissions trend is generally decreasing (-59.6% since 1990). The main contribution to total emissions is given by diesel vehicles, in 2015 equal to 97.8% out of the total. Despite of the decrease, road transport is the main source of emissions at national level in 2015 (39.5%).

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

Source categories for NFR Subsector 1.A.3.b	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
1.A.3.b.i Passenger cars	10.04	7.77	6.57	6.97	5.88	5.05	4.67	4.54	4.67	4.42
1.A.3.b.ii Light-duty vehicles	5.51	6.39	7.84	7.05	5.16	5.02	3.97	3.10	3.05	2.20
1.A.3.b.iii Heavy-duty vehicles including buses	6.91	6.73	5.59	4.66	3.27	3.24	2.98	2.67	2.58	2.53
1.A.3.b.iv Mopeds and motorcycles	0.62	0.83	0.77	0.59	0.26	0.25	0.20	0.19	0.19	0.17
Total emissions	**23.07**	**21.73**	**20.77**	**19.27**	**14.59**	**13.56**	**11.82**	**10.50**	**10.49**	**9.32**

Source: ISPRA elaborations

Emissions of SO_X, NH_3 and Pb (Table 3.24) are not key categories in 2015, despite emissions Pb from passenger cars are key categories in 1990 and emissions of SO_X, NH_3 and Pb from passenger cars are key categories in trend. Emissions of these pollutants deriving from road transport are irrelevant in 2015, compared to other sectors. Emissions of SO_X and Pb show strong decreases (since 2002, Pb resulting emissions are not exhaust), due to limits on fuels properties imposed by legislation. SO_X emissions decrease by 99.7%, representing 0.3% of the total in 2015. Emissions of Pb decrease of 99.7% and represent, in 2015, 4.3% of total national emissions. Emissions of NH_3, despite the strong increase since 1990, in 2015 account for just 1.6% 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	2011	2012	2013	2014	2015
SO_X (Gg)	129.66	71.70	11.93	2.21	0.43	0.43	0.43	0.42	0.43	0.37
NH_3 (Gg)	0.73	5.14	20.16	14.87	9.23	8.51	7.10	6.78	6.42	6.18
Pb (Mg)	3,851.12	1,663.67	693.95	12.48	11.54	11.59	10.94	10.66	11.19	10.93

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, time series resulting from the recalculation due to the application of COPERT 4 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 new 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 2017 submission the historical series has been revised according to the application of the model COPERT 4 v.11.4 for all vehicle categories except for CNG passenger cars, for which a country specific database has been used.

Regarding fuel consumption, values have been updated according to data published in 2017 in the new EUROSTAT format of the energy balance (http://dgsaie.mise.gov.it/dgerm/ben.asp).

As regards input fleet data, fleet values for mopeds have been updated according to data provided by the Ministry of Transport for the years 2012 – 2015, taken as reference because the mopeds fleet is considered to be completely registered since 2012.

Fleet values for urban buses in 2014 have been updated according to the updating of the data on urban public buses, published on CNIT 2014 – 2015.

The transition to version 11.4 of the model provided the chance for global checks and revisions of input data and parameters for the entire historical time series. Consequentially the fuel balancing process is applied, acting mainly on control variables such as mileage, with the aim to minimize the deviation between statistical and calculated fuel consumption values.

The final report on the physic-chemical characterization of fossil fuels used in Italy, carried out by the Fuel Experimental Station, has been used since 2015 submission, with the aim to improve fuel quality specifications. 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.

Since 2015 fuel information has been updated also as regards country specific fuel consumption factors for gasoline and diesel passenger cars on the basis of the results published by EEA in the report “Monitoring CO_2 emissions from passenger cars and vans in 2015” (EEA, several 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 in 2017 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 2016 (EMEP/EEA, 2016).

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.

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	2011	2012	2013	2014	2015
Diesel Consumption (TJ)	8,364.61	8,193.91	5,846.69	4,139.63	2,688.63	1,920.45	2,304.54	1,621.71	768.18	938.89
Emissions from diesel trains (Gg)										
NO_X	10.27	10.06	7.18	5.08	3.24	2.27	2.66	1.82	0.84	1.00
NMVOC	0.91	0.89	0.64	0.45	0.29	0.20	0.24	0.17	0.08	0.09
SO_X	1.18	0.77	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.00
NH_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$PM_{2.5}$	0.28	0.28	0.20	0.14	0.08	0.06	0.07	0.05	0.02	0.03
PM_{10}	0.28	0.28	0.20	0.14	0.09	0.06	0.07	0.05	0.02	0.03
TSP	0.29	0.28	0.20	0.14	0.09	0.06	0.07	0.05	0.02	0.03
BC	0.18	0.18	0.13	0.09	0.06	0.04	0.05	0.03	0.01	0.02
CO	2.10	2.05	1.47	1.04	0.67	0.48	0.58	0.41	0.19	0.24

Source: ISPRA elaborations

In this submission recalculations affected this category for the whole time series due to the adoption of the National Energy Balance figures officially provided to the OECD/IEA/EUROSTAT Joint Questionnaire and to the adoption of the updated factors of the EMEP/EEA Emission Inventory Guidebook 2016 (EMEP/EEA, 2016), for NO_X. NMVOC and PM, as well as the consideration of the European Directive 2004/26/EC (EC, 2004) introducing emission limits for the new rail traction engines for the same pollutants.

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 2015, 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 2015 with respect to emissions of SO_X, NO_X, PM_{10} and $PM_{2.5}$.

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, 2016). 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, 2016). 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, 2016), 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 Baltic sea, English channel and 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 46% of the fleet.

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

3.10.3 Time series and key categories

In Table 3.26 the list of key categories by pollutant identified for navigation in 2015, 1990 and at trend assessment is reported. Navigation is, in 2015, key category for many pollutants: SO_X, NO_X and PM, 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 2015, 1990 and in the trend*

	Key categories in 2015	*Key categories in 1990*	*Key categories in trend*
SOx	1A3dii	1A3dii	1A3dii
NOx	1A3dii		1A3dii
NMVOC			
PM_{10}	1A3dii	1A3dii	
$PM_{2.5}$	1A3dii	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	2011	2012	2013	2014	2015
Gasoline for recreational craft (Gg)	182.00	210.00	213.00	199.00	169.00	149.00	99.00	99.00	99.00	99.00
Diesel oil for inland waterways (Gg)	19.80	22.73	20.20	24.75	18.18	21.82	24.95	30.20	28.28	27.43
Fuels used in domestic cruise navigation (Gg)	778.06	706.38	811.37	739.97	725.35	678.27	611.22	575.01	572.60	538.52
Fuel in harbours (dom+int ships) (Gg)	748.46	692.95	818.48	758.89	743.90	695.61	626.85	589.72	587.24	552.29
Fuel in international Bunkers (Gg)	1,350.07	1,233.96	1,277.90	2,147.25	2,174.64	2,245.24	1,958.69	1,540.26	1,388.73	1,755.63
Emissions from National Navigation (Gg)										
Emissions of NOx	95.55	87.97	102.48	94.94	93.28	87.42	78.63	74.39	74.08	69.83
Emissions of NMVOC	46.11	52.42	50.17	43.28	31.82	27.47	18.49	17.82	17.19	16.66
Emissions of SOx	77.94	70.31	81.49	49.73	28.38	26.54	23.91	22.50	22.40	21.07
Emissions of $PM_{2.5}$	9.30	8.83	9.61	8.90	7.86	7.24	6.22	5.90	5.83	5.51
Emissions of PM_{10}	9.33	8.86	9.65	8.94	7.89	7.27	6.25	5.93	5.86	5.53
Emissions of CO	102.27	115.57	124.77	122.86	109.42	96.71	66.19	65.28	64.68	63.35

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

Recalculations, respect to the previous submission, regard emissions since 1990; specifically lubricants previously attributed to navigation, as fuel international bunkers, have been now attributed to the IPPU sector according to the 2006 IPCC Guidelines (IPCC, 2006) which requires to be estimated and reported in the energy sector only lubricants consumption for two stroke engines in road transport.

Recalculation affected also emissions from recreation crafts, in consideration of the European Directive 2003/44, from 2007, which establishes NOx, NMVOC, CO emission limits for new engines and of the update, for the whole time series, of NOx, NMVOC, CO, PM and NH_3 emission factors according to the EMEP/EEA Guidebook (EMEP/EEA, 2016).

3.10.6 Planned improvements

Further improvements will regard 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 pollutants 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.

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.

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**	**2011**	**2012**	**2013**	**2014**	**2015**
NOx	2.89	4.18	2.96	2.37	1.71	0.90	0.99	0.86	0.50	0.36
NMVOC	0.02	0.03	0.04	0.04	0.05	0.03	0.03	0.03	0.02	0.02
SOx	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
PM_{10}	0.02	0.03	0.05	0.03	0.03	0.02	0.02	0.02	0.01	0.02
CO	1.26	1.38	1.03	0.60	0.61	0.36	0.34	0.31	0.25	0.23

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 MW_{th}, 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 2015, 1990 and in the trend is reported.

Table 3.29 *List of key categories by pollutant in the civil sector in 2015, 1990 and trend*

	Key categories in 2015		*Key categories in 1990*		*Key categories in trend*		
SO_X			1 A 4 b i		1 A 4 a i		
NO_X	1 A 4 b i	1 A 4 c ii	1 A 4 c ii		1 A 4 a i	1 A 4 b 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 b i		
PM_{10}	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	
$PM_{2.5}$	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	
Pb	1 A 4 a i				1 A 4 a i		
Cd	1 A 4 a i		1 A 4 b i	1 A 4 a i	1 A 4 a i	1 A 4 b i	
Hg	1 A 4 a 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						
PCB					1 A 4 a 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. In the residential sector the emissions arise from the energy used in residential buildings, mainly for heating and the sector includes emission from household and gardening machinery. The Agriculture/ Forestry/ Fishing sector includes all emissions due to the fuel use 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.

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)). The national energy balance does separate energy consumption between civil and agriculture-fishing, but it does not distinguish between Commercial – Institutional and Residential. But this information is available in the Joint Questionnaire OECD/IEA/EUROSTAT prepared by the Ministry of Economical Development and officially sent to the international organizations. In this submission the updated fuel consumption time series according to the joint Questionnaire have been updated for the following fuels: steam coal, coke oven coke, residual oil, gasoil, kerosene, LPG, gas work gas.

For natural gas, which have not been yet updated with data reported to the international organizations, total consumption is subdivided between commercial and residential on the basis of the percentage figures estimated by ENEA and reported in its annual energy report (ENEA, several years).

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	2011	2012	2013	2014	2015
					TJ					
1 A 4 a i Commercial / Institutional: Stationary plants	213,278	259,740	318,033	431,470	496,865	427,362	425,566	422,050	374,818	402,137
1 A 4 b i Residential: Stationary plants	1,002,188	1,006,045	1,040,976	1,181,750	1,235,229	1,074,934	1,153,137	1,150,737	958,697	1,068,422
1 A 4 b ii Residential: Household and gardening (mobile)	466	571	373	154	66	57	57	57	57	57
1 A 4 c i Agriculture/Forestry/Fishing: Stationary	9,684	9,508	8,176	10,247	8,833	8,227	7,883	7,825	7,160	8,234
1 A 4 c ii Agriculture/Forestry/Fishing: Off-road Vehicles and Other Machinery	96,471	101,859	94,605	95,805	84,404	82,917	79,717	79,715	80,014	81,208
1A 4 c iii Agriculture/Forestry/Fishing: National Fishing	8,407	9,645	8,578	10,457	7,726	7,724	7,042	6,189	6,445	6,189
1 A 5 b Other, Mobile (Including military, land based and recreational boats)	14,830	20,800	11,587	16,935	8,995	7,110	4,594	8,061	7,959	6,384

The emission factors used derive from the EMEP/EEA Emission Inventory Guidebook 2009 (EMEP/EEA, 2009).

3.12.3 Methodological issues

A national methodology has been developed and applied to estimate NO_X emissions from gas powered plants and all emissions for wood combustion while emissions from waste combustion in incinerator with energy recovery have been calculated from the database of incinerator plants which includes plant specific emission factors on the basis of their technology and measurements data (ENEA-federAmbiente, 2012). More detail information is available in the relevant paragraph of the waste sector chapter.

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 have been 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**
			g/Gj			
1 A 4 a i Commercial / Institutional: Stationary	50	48.5	40.2	35.2	32.4	30.6
1 A 4 b i Residential: Stationary plants	50	48.2	38.6	32.4	31.3	30.7

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. The technologies assessed by the abovementioned surveys and their distribution are reported in Table 3.32.

Table 3.32 *Distribution of wood combustion technologies*

	Distribution of wood combustion technologies		
	1999	2006	2012
		%	
Fireplaces	51.3	44.7	51.2
Stoves	28.4	27.6	22.9
Advanced fireplaces	15.4	20.2	15.8
Pellet stoves	0	3.1	4.0
Advanced stoves	4.8	4.4	6.0

Average emission factors for 1999, 2006 and 2012 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.

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.

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**
			g/Gj			
NO_x	50	55	59	61	61	60
CO	6000	5791	5591	5427	5395	5275
NMVOC	762	715	672	643	638	631
SO_2	10	11	12	13	13	12
NH_3	9	7	6	6	6	6
PM10	507	465	428	408	404	407
PM2.5	503	461	424	404	400	402
BC	40	37	35	34	34	34
PAH	0.25	0.24	0.23	0.22	0.22	0.22
Dioxin (µg/GJ)	0.48	0.47	0.45	0.44	0.44	0.42
PCB	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
As	0.001	0.001	0.001	0.001	0.001	0.0005
Cd	0.002	0.002	0.001	0.001	0.001	0.001
Cr	0.001	0.002	0.003	0.003	0.003	0.003
Cu	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
Ni	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
Se	0.001	0.001	0.001	0.001	0.001	0.0005
Zn	0.10	0.10	0.10	0.09	0.09	0.09
B(a)P	0.07	0.07	0.06	0.06	0.06	0.07
B(b)F	0.09	0.08	0.08	0.08	0.08	0.08
B(k)F	0.04	0.04	0.04	0.04	0.04	0.03
IND	0.05	0.05	0.05	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 statistics for 2012 and 2013 of wood and pellet fuel consumption at national and regional level including the information on the relevant equipments. 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 equipments 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 gradually shift of diesel fuel to gas, concerning SO_X, and to a replacement of classic boilers with those with low emission for NO_X. All the other pollutants have a growing trend, as a consequence of the increase of wood combustion.

More in detail the decrease of SO_2 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_2 emission factors for 1990 and 2015 by fuels are shown in the following box.

EMISSION FACTORS (kg/Gj)		
FUEL	1990	2015
steam coal	0.646	0.646
coke oven coke	0.682	0.682
wood and similar	0.010	0.012
municipal waste	0.069	0.050
biodiesel	0.047	0.047
residual oil	1.462	0.146
gas oil	0.140	0.047
kerosene	0.018	0.018
natural gas	-	-
biogas	-	-
LPG	-	-
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	2011	2012	2013	2014	2015
SO_X (Gg)	1 A 4	96.05	42.23	25.91	22.31	11.59	9.20	10.01	9.99	8.96	9.67
	1 A 5	1.19	0.81	0.21	0.17	0.13	0.11	0.04	0.10	0.14	0.12
NO_X (Gg)	1 A 4	175.23	187.98	177.23	168.41	147.48	133.80	132.86	133.19	123.71	127.61
	1 A 5	11.16	11.99	7.24	13.50	6.11	4.68	3.93	6.01	4.35	3.29
CO (Mg)	1 A 4	1093.01	1088.79	1028.10	997.65	1715.96	1132.97	1557.55	1559.44	1354.22	1512.49
	1 A 5	65.12	79.02	45.49	54.48	17.33	14.12	6.32	13.90	19.55	16.49
PM10 (Mg)	1 A 4	84.59	89.72	85.65	81.03	129.84	85.66	119.67	119.04	103.10	115.07
	1 A 5	1.27	1.54	0.90	1.60	0.81	0.63	0.49	0.78	0.61	0.47
PM2.5 (Mg)	1 A 4	83.77	89.03	84.86	80.23	128.48	84.77	118.39	117.77	102.01	113.84
	1 A 5	1.27	1.54	0.90	1.60	0.81	0.63	0.49	0.78	0.61	0.47
BC (Mg)	1 A 4	14.89	16.13	14.71	12.46	13.77	9.81	12.32	11.87	10.39	11.23
	1 A 5	0.72	0.82	0.49	0.92	0.46	0.35	0.29	0.45	0.33	0.25
Pb (Mg)	1 A 4	81.95	34.28	24.64	46.34	73.73	56.97	67.78	73.54	75.33	77.69
	1 A 5	16.34	4.22	1.16	0.00	0.00	0.00	0.00	0.06	0.06	0.12
Cd (Mg)	1 A 4	1.51	1.21	1.74	2.62	2.56	1.95	2.32	2.49	2.52	2.63
	1 A 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hg (Mg)	1 A 4	0.61	0.71	1.04	1.98	2.43	1.94	2.23	2.42	2.48	2.57
	1 A 5	-	-	-	-	-	-	-	-	-	-
PAH (Mg)	1 A 4	32.05	35.42	35.89	39.07	68.53	43.88	62.23	62.41	54.14	60.78
	1 A 5	0.02	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.00	0.00
HCB (Kg)	1 A 4	1.88	2.87	6.30	6.30	4.25	2.77	3.29	2.91	2.61	2.79
	1 A 5	-	-	-	-	-	-	-	-	-	-
PCB (Kg)	1 A 4	14.59	17.96	25.40	35.86	32.51	22.53	29.14	29.88	28.14	30.23
	1 A 5	-	-	-	-	-	-	-	-	-	-

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

Several recalculations affected the 2016 submission. The main one regard the update of the complete time series of steam coal, coke oven coke, residual oil, gasoil, kerosene, LPG, gas work gas fuel consumption for heating in commercial, institutional and agriculture sectors according to data available in the Joint Questionnaire OECD/IEA/EUROSTAT prepared by the Ministry of Economical Development and officially sent to the international organizations. Also kerosene and gasoline fuel consumptions for national fishing have been updated according to the OECD/IEA/EUROSTAT energy balance figures.

Energy recovery from waste reported in the commercial heating has been updated from 2011; in particular activity data have been updated for 2014 for urban waste and from 2011 for industrial waste. Further details are reported in the waste chapter. Recalculations affected mainly heavy metals, HCB and PCB.

For 2013 and 2014, NO_X emission factors for natural gas consumption in residential and commercial small combustion plants have been updated on the basis of data published in the annual report of the equipment producer association (Assotermica, several years).

3.12.7 Planned improvements

On the basis of the surveys on wood consumption and combustion technologies carried out by ISPRA (SCENARI/ISPRA, 2013) and by ISTAT (ISTAT, 2014), the updating of average emission factors is planned for the next submission.

An in depth analysis of emission factors resulting from the experimental study carried out by SSC (SSC, 2012) for biomass and their comparison with the values suggested by the last version of the EMEP/EEA Guidebook (EMEP/EEA, 2016) will be carried out and emission factors will be updated if needed.

3.13 Fugitive emissions from natural gas distribution (NFR SUBSECTOR 1.B.2b)

NMVOC fugitive emissions from the distribution 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. The methodology and references are reported in detail in the NIR (ISPRA, 2017[a]). CH4, 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,). NMVOC and CO2 emissions have been calculated considering CO_2 content in the leaked natural gas.

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 3.35 *Average composition for pipelines natural gas and main parameters*

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
HCV (kcal/m_3)	9,156	9,193	9,221	9,267	9,331	9,287	9,304	9,280	9,262	9,309
NCV (kcal/m_3)	8,255	8,290	8,325	8,360	8,418	8,376	8,393	8,370	8,354	8,397
Molecular weight	17.03	17.19	17.37	17.44	17.46	17.26	17.41	17.32	17.35	17.33
Density (kg/Sm_3)	0.72	0.73	0.74	0.74	0.74	0.73	0.74	0.73	0.73	0.73

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
CH_4 (molar %)	94.30	93.36	92.22	91.93	92.03	93.08	92.16	92.77	92.62	92.72
NMVOC (molar %)	3.45	4.09	4.84	5.35	5.74	5.00	5.48	5.04	5.04	5.26
CO_2 (molar %)	0.22	0.20	0.18	0.49	0.75	0.68	0.61	0.61	0.75	0.70
Other no carbon gas (molar %)	2.03	2.34	2.76	2.24	1.48	1.24	1.75	1.59	1.58	1.32
CH_4 (weight %)	88.83	87.14	85.16	84.53	84.54	86.52	84.89	85.94	85.64	85.80
NMVOC (weight %)	7.33	8.62	10.00	10.73	11.27	9.79	10.81	9.99	9.92	10.34
CO_2 (weight %)	0.57	0.51	0.47	1.23	1.89	1.73	1.54	1.54	1.91	1.78
Other no carbon gas (weight %)	3.27	3.74	4.37	3.51	2.30	1.95	2.76	2.53	2.52	2.10

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 3.36 provides the trend of natural gas distribution network length for each pipeline material and the average CH4 emission factor.

Table 3.36 *Length of low and medium pressure distribution network (km) and network emission factors for CH_4 and NMVOC*

Material	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Steel and cast iron (km)	102,061	131,271	141,848	154,886	198,706	197,369	199,899	200,647	202,137	203,116
Grey cast iron (km)	24,164	22,784	21,314	15,080	4,658	4,519	4,414	3,727	3,348	2,398
Polyethylene (km)	775	8,150	12,550	31,530	49,663	51,053	52,073	53,548	54,639	56,943
Total (km)	**127,000**	**162,205**	**175,712**	**201,496**	**253,027**	**252,940**	**256,386**	**257,922**	**260,124**	**262,457**
CH_4 EF (kg/km)	**1,958**	**1,417**	**1,227**	**1,000**	**715**	**707**	**676**	**660**	**626**	**540**
NMVOC EF (kg/km)	**161**	**143**	**136**	**109**	**97**	**96**	**100**	**99**	**97**	**87**

No recalculations occurred in the 2017 submission and 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 2015, industrial processes account for 10.1% of SO_2 emissions, 0.6% of NO_X, 0.1% of NH_3, 4.8% of NMVOC and 2.7% of CO. About particulate matter, in 2015 this sector accounts for 5.0% of PM10 emissions and 4.4% 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 25.7% of Pb emissions, 16.4% of Cd and 32.2% of Hg. Regarding POPs emissions, 10.0% of PAH total emissions is emitted from industrial processes as well as 27.4% of dioxins and 40.6% of PCB.

In 2015, *iron and steel* sector (2C1) is a key category at level assessment for PM10, PM2.5, Pb, Cd, Hg, PAH, PCDD/PCDF and PCB; emissions from *cement production* (2A1) is a key category source for SO_2 emissions. In 1990 *other chemical industry* (2B10a) is a key category for Hg and *iron and steel production* (2C1) is a key category for PM10, Cd, Hg, PAH, PCDD/PCDF and PCB. At trend assessment, *iron and steel* sector is key category for Pb, Hg, PAH, PCDD/PCDF and PCB while *cement production* is a key category for SO_2 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, 2013), 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.

Mineral products (2A)

In this sector emissions from the following processes are estimated and reported: cement production and lime production.

Cement production (2A1), is relevant for SO_2 and PM10 emissions and accounts for 5.1% and 1.5% of the respective total national emissions in 2015.

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 27 and the reduction of clinker production has been confirmed in 2015. Actually, 25 companies (68 plants of which: 37 full cycle and 31 grinding plants) operate in this sector: multinational companies and small and medium size enterprises (operating at national or only at local level) are present in the country. As for the localization of the operating plants: 44% is in northern Italy, 16% is in the central regions of the country and 40% is in the southern regions and in the islands (AITEC, 2015 In Italy different types of cement are produced; as for 2015 AITEC, the national cement association, has characterised the national production as follows: 70% is CEM II (Portland composite cement); 13.74% is CEM I (Portland ordinary cement); 12.6% is CEM IV (pozzolanic cement) and 3% is CEM III (blast furnace cement). Clinker production has been decreasing since 2007 and decreased by 1.9% in 2015 compared to 2014; clinker demand in cement production was about 78% in 2015 (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) and MSE (MSE, several years since 2009).

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 plants 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 IPCC 96 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.

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. 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 2015 to 217,509 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 0.17 g Hg/t in 2015. 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.

Emissions from sulphuric acid production, also reported in *other chemical industry* (2B10a), although not key category account for 3.8% of total SO_X emissions in 2015. 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.

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 is 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 2015, there are only two of the above mentioned plants, one of which lacks BOF; oxygen steel production represents about 21.8 % of the total production and the arc furnace steel the remaining 78.2 % (FEDERACCIAI, several years). Currently, long products represent about 45% of steel production in Italy, flat products about 43%, and pipe the remaining 12%. Almost the whole 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 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 1990-2015. 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. 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 1A2 Manufacturing Industries and Construction category.

In 2015, *iron and steel sector* (2C1) is key category for PM10, PM2.5, Pb, Cd, Hg, PAH, PCDD/PCDF and PCB**.** In Table 4.1 relevant emission factors are reported.

Table 4.1 ***Emission factors for iron and steel for the year 2015***

		PM10 [g/Mg]	PM2.5 [g/Mg]	Cd [mg/Mg]	Hg [mg/Mg]	Pb [mg/Mg]	PCB [mg/Mg]	PAH [mg/Mg]	PCDD/PCDF [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	8.3	6.6						

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 to the stack; emissions are therefore reported in the energy sector in 1.A.2f category. In 2015 the average emission factor is equal to 0.16 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 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.

Emission factors used in 1990 estimates generally derive from Guidebook EMEP/CORINAIR.

The remaining categories of metal production industry represent less than 2% for each pollutant.

Other production (2G – 2H – 2L)

In 2H sector, non-energy emissions from *pulp and paper* as well as *food and drink* production, especially wine and bread, are reported. Lead emissions from *batteries manufacturing* can be found in 2L sector. 2G sector includes NMVOC emissions due to the *use of lubricants*.

Emissions from these categories are usually negligible except NMVOC emissions from *food and drink* (2H2) accounting for 2.6% of the national total in 2015. 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).

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 2015***

	2A1	2A2	2B1	2B2	2B3	2B6	2B7	2B10a	2C1	2C2	2G	2H1	2H2	2L
							%							
SO_x	5.07		0.006			0.20		3.81	1.01					
NO_x			0.05	0.04	0.003	0.006		0.21	0.29					
NH_3			0.00	0.000			0.09	0.02						
NMVOC			0.01					0.33	0.35		1.34	0.15	2.61	
CO			0.003				0.29	0.48	1.92					
PM10	1.51	0.65				0.00		0.27	2.60				0.01	
PM2.5	1.69	0.15				0.00		0.15	2.38					
BC	0.34	0.00				0.00		0.02	0.09					
Pb									24.95					0.79
Cd								0.90	15.54					
Hg								0.46	31.72					
PAH									10.05					
Dioxin									27.38					
HCB														
PCB									40.59					

Note: key categories are shaded in blue

There is a general reduction of emissions in the period 1990 - 2015 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.

Mineral products (2A)

As above mentioned, PM10 emission factor for cement production is set constant from 1990 to 2015 while SO_2 emission factor reduced from 1990 to 1995 and is set constant in the subsequent years.

Consequently, SO_2 and PM10 emissions trends 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 – 2015 (Gg)***

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
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)	21.2	10.6	12.3	14.2	10.3	9.8	7.9	6.9	6.5	6.2
PM10 emissions [Gg]	5.5	4.6	5.3	6.1	4.5	4.3	3.4	3.0	2.8	2.7

Chemical industry (2B)

Other chemical industry (2B10a) was a key category for Hg emissions in 1990. 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 0.17 g Hg/t in 2015. 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 – 2015***

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Activity data [Gg]	1,043	869	786	535	258	279	298	226	221	218
Hg emissions [Mg]	2.82	1.65	0.94	0.48	0.12	0.16	0.05	0.04	0.03	0.04

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.

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 2015 average emission factor is equal to 0.16 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 – 2015***

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Steel production **EAF** [kt]	15,102	16,107	15,879	17,661	17,115	18,795	17,912	17,250	17,192	17,255
Cd emissions **EAF** [Mg]	1.1	1.1	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Cd emissions **2C1** [Mg]	1.3	1.4	1.1	1.2	1.1	1.2	1.1	1.0	1.0	1.0
Hg emissions **EAF** [Mg]	2.3	2.4	2.4	2.6	2.6	2.8	2.7	2.6	2.6	2.6
Hg emissions **2C1** [Mg]	2.3	2.5	2.4	2.7	2.6	2.9	2.7	2.6	2.6	2.6
Pb emissions **EAF** [Mg]	52.1	55.6	54.8	60.9	59.0	64.8	61.8	59.5	59.3	59.5

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Pb emissions **2C1** [Mg]	61.1	65.7	64.1	71.0	66.5	73.4	69.9	65.4	65.0	63.7
PCB emissions **EAF** [kg]	54.4	58.0	57.2	63.6	61.6	67.7	64.5	62.1	61.9	62.1
PCB emissions **2C1** [kg]	91.7	100.0	95.8	105.7	92.7	103.4	98.1	86.7	85.4	79.3
PCDD/PCDF emissions **EAF** [g T-eq]	67.2	71.7	70.7	78.6	76.2	83.6	79.7	76.8	76.5	76.8
PCDD/PCDF emissions **2C1** [g T-eq]	67.2	71.7	70.7	78.6	76.2	83.6	79.7	76.8	76.5	76.8

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. In lack of information for the years backwards, the default CORINAIR EF was used.

For PCB and PCDD/PCDF, emission factors are constant from 1990 to 2015 and emission trends are ruled by activity data.

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 considering, since 2000, 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 has been 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 – 2015***

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Pig iron production [Gg]	11,852	11,678	11,209	11,424	8,555	9,837	9,424	6,933	6,434	5,051
Steel production BOF [Gg]	10,365	11,664	10,744	11,688	8,635	9,940	9,345	6,830	6,523	4,763
PAH emissions i.p.* [Mg]	41.9	41.3	11.7	12.1	9.2	10.5	10.1	7.6	7.1	5.8
PAH emissions 2C1 [Mg]	44.9	44.5	14.3	15.1	11.9	13.5	13.0	10.2	9.7	8.2

*i.p.: integrated plants

Other production (2G – 2H – 2L)

Emissions from these categories are usually negligible except for NMVOC emissions from *food and* *drink* (2H2) accounting for 2.6% of the national total. Emissions from this 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 – 2015*

	1990	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Activity data - Bread [Gg]	4,153	3,882	3,565	4,109	4,161	3,737	3,764	3,486	3,423	3,391
Activity data – Wine [10^6 dm^3]	5,521	5,620	5,409	5,057	4,673	4,270	4,107	4,797	4,209	4,936
Activity data – Beer [10^6 dm^3]	1,215	1,199	1,258	1,280	1,281	1,341	1,348	1,326	1,352	1,402
Activity data – Spirits [10^6 dm^3]	268	232	206	161	115	103	102	92	98	98
NMVOC emissions [Gg]	31.7	29.2	26.8	27.5	25.9	23.3	23.3	22.1	21.7	22.0

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 2010 is reported in Figure 4.1; methodologies are described in the relevant publication (ISPRA, 2009).

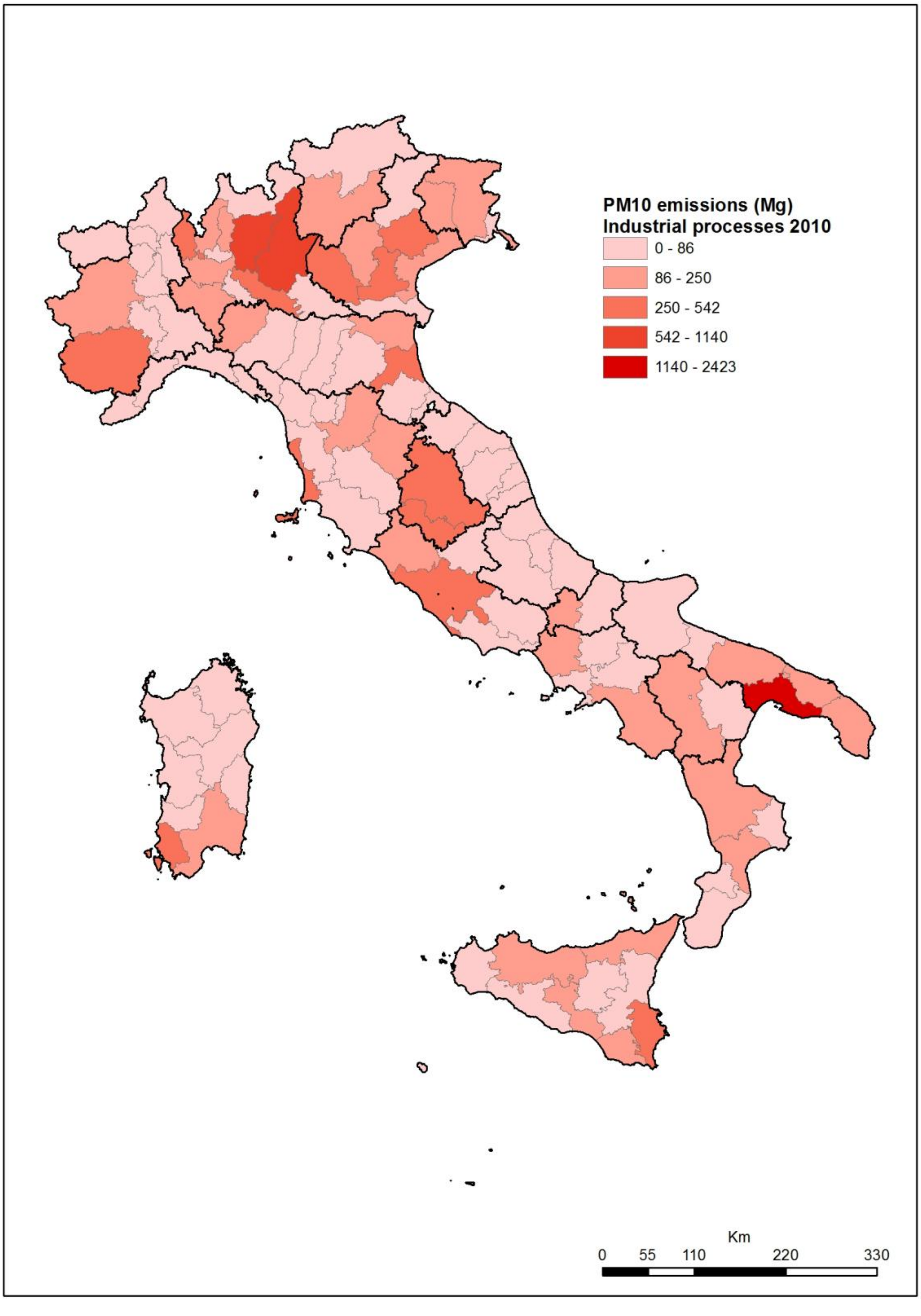

Figure 4.1 *PM10 emissions from industrial processes in 2010 (t)*

4.5 Recalculations

Metal production (2C)

Recalculations occurred in 2014 estimates because of the update of activity data.

Other production (2G – 2H – 2L)

Recalculations occurred in 2014 for NMVOC emissions because of the update of activity data for bread production.

4.6 Planned improvements

In the last years, 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.

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.

No other emissions from the sector occur.

NMVOC emissions from 2D3a, 2D3d, 2D3g and 2D3i are key categories in 2015; the same categories were also key categories in 1990. For the trend 1990-2015, 2D3a, 2D3d and 2D3g result as key categories.

The sector accounts, in 2015, for 42.6% of total national NMVOC emissions, whereas in 1990 the weight out of the total was equal to 31.7%. Total sectoral NMVOC emissions decreased by 41.6%, between 1990 and 2015.

PM, 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 2015.

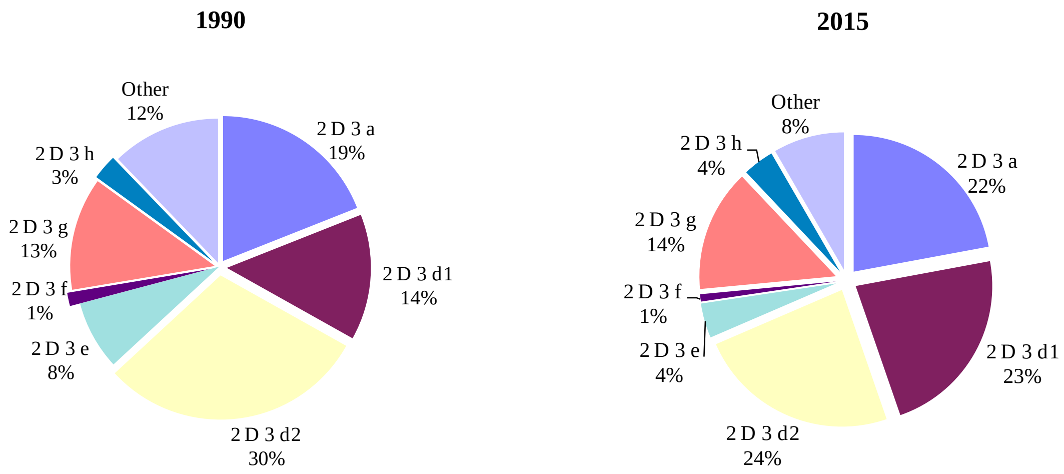

Figure 5.1 *Share of NMVOC emissions for the solvent use sector in 1990 and 2015*

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 key categories of NMVOC emissions in the following sections.

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.

<u>Activity data</u>

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.

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 in 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.

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.

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 category 3A2 are decreasing constantly from 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 in 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).

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%, in 1995 represented 90% and in 1999 up to 100%.

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, expressed as kg 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.

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.

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.

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.

Other product use (2D3i)

The category includes NMVOC emissions from the application of glues and adhesives, which account for about 90% of the emission 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 2015, for about 42.6% of total national NMVOC emissions, whereas in 1990 the weight out of the total was equal to 31.7%. PM, BC and PAH emissions are also estimated in this sector but they account for less than 1%.

NMVOC emissions from the sector decreased from 1990 to 2015 of about 41.6%, from 604 Gg in 1990 to 353 Gg in 2015, 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. In 2015, specifically, the reduction of emissions from paint application, which dropped by 38% as compared to 1990, is due to the implementation of the Italian Legislative Decree 161/2006.

Figure 5.2 shows emission trends from 1991 to 2015 with respect to 1990 by sub-sector.

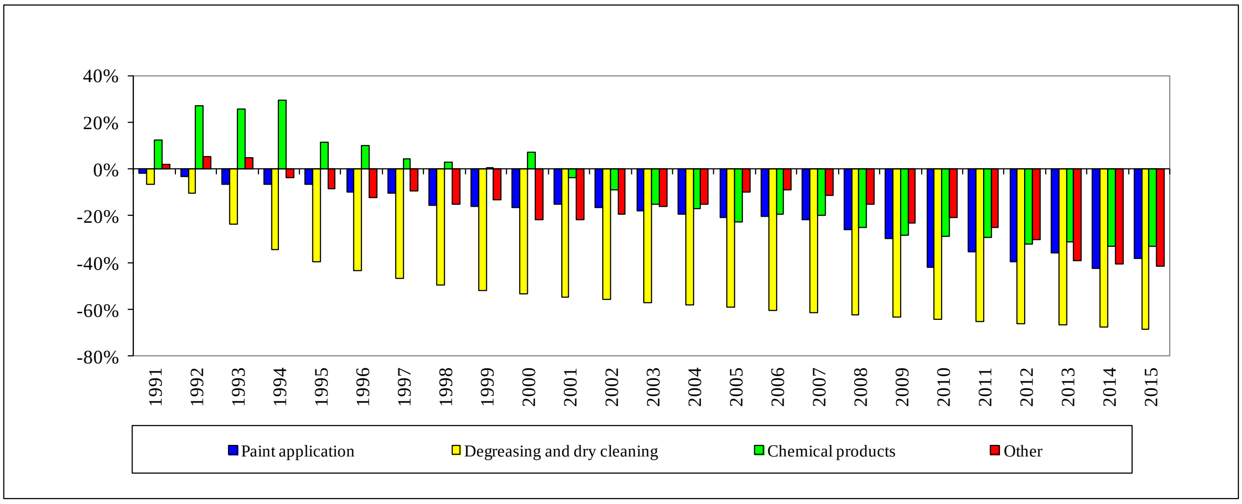

Figure 5.2 *Trend of NMVOC emissions from 1991 to 2015 as compared to 1990*

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 2015*

	2D3a	2D3b	2D3c	2D3d	2D3e	2D3f	2D3g	2D3h	2D3i
SO_x									
NO_x									
NH_3									
NMVOC	**9.41**	0.75	0.002	**19.80**	1.75	0.37	**6.16**	1.57	**2.84**
CO									
PM10		0.97	0.03				0.01		
PM2.5		0.15	0.01				0.01		
BC		0.06	0.00001						
Pb									
Cd									
Hg									
PAH	0.01								
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.

Table 5.2 *Activity data in the IPPU - Solvent and other product use sector*

			1990	1995	2000	2005	2010	2015
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	1,323,107
06 01 02	Paint application : car repairing	*Mg paint*	22,250	17,850	24,276	23,475	18,545	23,901
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
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
06 01 05	Paint application : coil coating	*Mg paint*	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
06 01 07	Paint application : wood	*Mg paint*	150,000	150,000	140,000	140,000	123,250	80,000
	Other industrial paint application	*Mg paint*	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
06 02 02	Dry cleaning	*machines*	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
06 03 02	Polyvinylchloride processing	*Mg product*	617,600	575,600	405,285	348,497	0	0
06 03 03	Polyurethane processing	*Mg product*	145,700	230,633	350,187	175,278	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
06 03 05	Rubber processing	*Mg product*	671,706	700,859	810,124	831,187	607,667	545,989
06 03 06	Pharmaceutical products manufacturing	*Mg product*	80,068	88,094	104,468	106,861	110,183	120,904
06 03 07	Paints manufacturing	*Mg product*	697,129	747,417	900,683	964,631	891,882	866,285
06 03 08	Inks manufacturing	*Mg product*	87,527	110,667	132,256	132,521	133,979	108,600
06 03 09	Glues manufacturing	*Mg product*	111,683	266,169	302,087	331,770	317,560	249,152
06 03 10	Asphalt blowing	*Mg product*	77,248	70,336	77,408	88,896	65,000	25,000
06 03 12	Textile finishing	*1000 m2*	1,332,679	1,301,105	1,173,047	987,705	831,236	631,573
06 03 13	Leather tanning	*1000 m2*	173,700	183,839	200,115	157,891	186,824	162,500
06 04	**Other use of solvents and related activities**							
06 04 01	Glass wool enduction	*Mg product*	105,029	119,120	139,421	129,958	115,923	88,658
06 04 02	Mineral wool enduction	*Mg product*	0	11,000	18,000	20,500	0	0
06 04 03	Printing industry	*Mg ink*	73,754	91,667	100,690	111,550	98,206	88,029
06 04 04	Fat, edible and non edible oil extraction	*Mg product*	5,070,398	7,560,387	6,539,796	7,939,548	7,088,890	5,185,738
06 04 05	Application of glues and adhesives	*Mg product*	98,500	234,751	266,996	292,687	280,150	219,801
06 04 08	Domestic solvent use (other than paint application)(k)	*Mg product*	1,938,779	2,282,020	2,410,338	2,767,759	2,614,274	2,275,335
06 04 09	Vehicles dewaxing	*vehicles*	2,540,597	1,740,212	2,361,075	2,238,344	1,972,070	1,594,259

Table 5.3 *Emission factors in the IPPU - Solvent and other product use sector*

			1990	1995	2000	2005	2010	2015
06 01	**Paint application**							
06 01 01	Paint application : manufacture of automobiles	*g/vehicles*	8,676	6,296	4,833	4,065	2,854	3,036
06 01 02	Paint application : car repairing	*g/Mg paint*	700,000	700,000	605,500	605,500	497,810	770,892
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	256,086
06 01 04	Paint application : domestic use (except 06.01.07)	*g/Mg paint*	126,450	113,100	99,750	99,750	67,710	96,450
06 01 05	Paint application : coil coating	*g/Mg paint*	200,000	200,000	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
06 01 07	Paint application : wood	*g/Mg paint*	446,500	425,000	406,300	390,750	377,250	354,000
	Other industrial paint application	*g/Mg paint*	530,000	530,000	439,900	337,583	250,000	250,000
06 02	**Degreasing, dry cleaning and electronics**							
06 02 01	Metal degreasing	*g/Mg solvents*	900,000	900,000	900,000	900,000	900,000	900,000
06 02 02	Dry cleaning	*g/machines*	306,000	154,000	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
06 03 02	Polyvinylchloride processing	*g/Mg product*	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
06 03 04	Polystyrene foam processing (c)	*g/Mg product*	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
06 03 06	Pharmaceutical products manufacturing	*g/Mg product*	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	10,831	12,163
06 03 08	Inks manufacturing	*g/Mg product*	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
06 03 10	Asphalt blowing	*g/Mg product*	544	544	544	544	544	544
06 03 12	Textile finishing	*g/1000 m2*	296	296	296	296	296	296
06 03 13	Leather tanning	*g/1000 m2*	150,000	150,000	125,000	105,378	82,267	71,000
06 04	**Other use of solvents and related activities**							
06 04 01	Glass wool enduction	*g/Mg product*	800	800	800	800	800	800
06 04 02	Mineral wool enduction	*g/Mg product*	300	300	300	300	300	300
06 04 03	Printing industry	*g/Mg ink*	234,649	228,190	184,332	174,227	174,227	150,000
06 04 04	Fat, edible and non edible oil extraction	*g/Mg product*	790	704	706	691	700	723
06 04 05	Application of glues and adhesives	*g/Mg product*	600,000	151,230	108,086	84,190	84,190	84,190
06 04 08	Domestic solvent use (other than paint application)(k)	*g/Mg product*	60,117	52,262	42,356	46,153	42,172	35,000
06 04 09	Vehicles dewaxing	*g/vehicles*	1,000	1,000	1,000	1,000	1,000	1,000

5.4 QA/QC and verification

Data production and consumption time series for some activities (paint application in constructions and buildings, polyester processing, polyurethane processing, pharmaceutical products, paints manufacturing, glues manufacturing, textile finishing, leather tanning, fat edible and non edible oil extraction, application of glues and adhesives) are checked with data acquired by the National Statistics Institute (ISTAT, several years [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 2010 is reported in Figure 5.3; methodologies are described in the relevant publication (ISPRA, 2009).

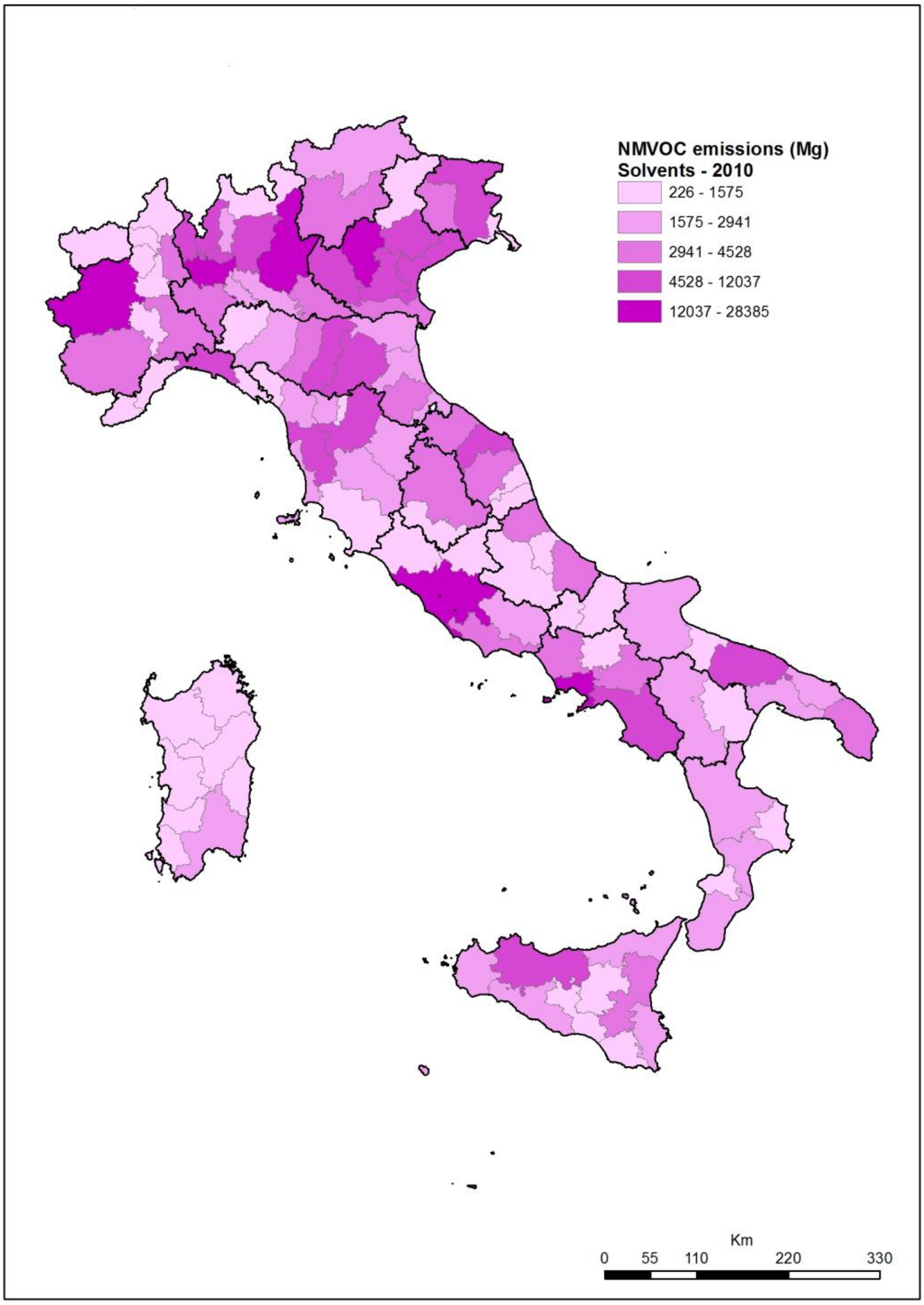

Figure 5.3 *NMVOC emissions from solvent and other product use in 2010 (t)*

5.5 Recalculations

Minor recalculations occurred because of the update of some activity data from 2012 in manufacture of automobiles and in 2014 for printing industry, glass wool enduction and fat edible and non edible oil extraction.

5.6 Planned improvements

Specific developments will regard the improvement of emission factors for some relevant categories.

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 PM_{10}, $PM_{2.5}$, BC, TSP, NO_X, NMVOC, CO, 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).

In 2015, key categories level were identified for NH_3 emissions (3B1a, 3B1b, 3B3, 3B4gii, 3Da1 and 3Da2a). In 1990 similar figures were obtained except for NH_3 emissions 3B4gii, which was not key category, and for HCB emissions 3Df (use of pesticides) and PM_{10} ,3B4gii manure management - broilers, which were key categories. For the trend analysis, key categories were related to NH_3 emissions (3B1a, 3B1b, 3B3, 3B4a, 3B4gi, 3B4gii, 3Da2a and 3Da2c) and HCB (3Df).

In 2015, NH_3 emissions from the agriculture sector were 377.9 Gg (96.1% of national emissions) where 3B and 3D categories represent 55.8% and 40.3% of total national emissions. The trend of NH_3 from 1990 to 2015 shows a 17.9% 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 2015 is shown in Figure 6.1.

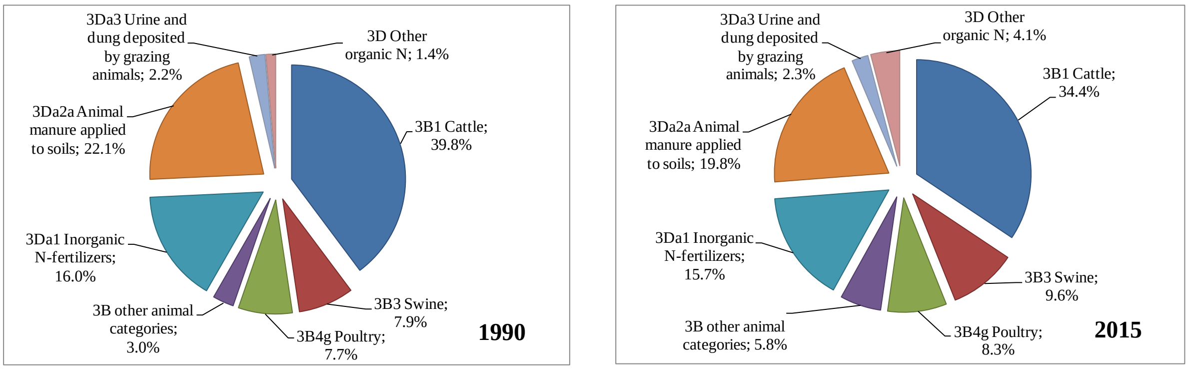

Figure 6.1 *Share of NH_3 emissions in the agriculture sector for 1990 and 2015*

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://agri.istat.it/jsp/Introduzione.jsp. 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.

[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

Table 6.1 *Time series of animals*

Year	Dairy cattle	Non-dairy cattle	Buffalo	Sheep	Goats	Horses	Mules/asses	Swine	Rabbits	Poultry	Fur animals
	heads										
1990	2,641,755	5,110,397	94,500	8,739,253	1,258,962	287,847	83,853	6,949,091	14,893,771	173,341,562	325,121
1995	1,754,981	4,142,544	354,402	7,942,641	959,915	373,327	50,966	7,602,093	17,549,225	200,718,160	160,000
2000	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
2005	1,754,981	4,142,544	354,402	7,942,641	959,915	373,327	50,966	7,602,093	17,549,225	200,718,160	160,000
2010	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
2011	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
2012	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
2013	1,842,004	4,409,921	205,093	7,954,167	945,895	278,471	30,254	7,484,162	20,504,282	188,595,022	200,000
2014	1,746,140	4,086,317	365,086	7,900,016	982,918	373,324	46,475	7,588,658	17,957,421	198,346,719	125,000
2015	1,754,981	4,142,544	354,402	7,942,641	959,915	373,327	50,966	7,602,093	17,549,225	200,718,160	160,000

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	Nitrogen content ($t\ N\ yr^{-1}$) 1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Ammonium sulphate	10%	50,762	61,059	36,698	27,855	32,568	27,418	27,246	15,599	13,597	16,986
Calcium cyanamide	2%	3,310	507	3,003	2,357	4,958	4,675	4,408	4,164	3,091	3,046
Nitrate (*)	2%	157,221	189,907	164,134	167,872	72,833	72,334	103,606	72,930	92,569	91,357
Urea	15%	291,581	321,196	329,496	317,814	209,829	219,033	344,981	282,197	246,957	266,154
Other nitric nitrogen	2%	-	-	3,204	5,219	3,332	3,479	4,122	2,908	1,943	1,189
Other ammoniacal nitrogen	2%	-	-	6,278	18,069	12,412	12,993	13,517	3,820	4,279	7,035
Other amidic nitrogenous	15%	-	-	6,988	17,420	15,366	17,663	23,906	19,572	22,855	11,796
Phosphate nitrogen	5%	112,237	99,468	77,916	69,758	45,837	47,272	51,277	50,726	36,773	35,054
Potassium nitrogen	2%	3,937	2,876	5,291	12,289	15,955	17,758	16,720	24,322	8,922	9,077
NPK nitrogen	2%	138,018	101,528	113,897	106,384	64,462	65,444	75,142	48,097	48,979	50,174
Organic mineral	2%	444	20,960	38,688	34,809	19,085	27,897	18,641	22,209	25,161	25,986
Total		**757,509**	**797,500**	**785,593**	**779,846**	**496,637**	**515,966**	**683,566**	**546,542**	**505,126**	**517,854**

(*) 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/CORINAIR, 2007; EMEP/EEA, 2013; EMEP/EEA, 2016), 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 (Cóndor and De Lauretis, 2007). 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*).

Manure management (3B)

For 3B category, Italy has estimated emissions for pollutants recommended in the *2013* and *2016 EMEP/EEA Guidebook* (NH_3, NO_X, NMVOC, PM_{10}, and $PM_{2.5}$). 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), T1 (NOx, NMVOC, PM_{10}, $PM_{2.5}$)	NS	CS (NH_3), D (NOx, NMVOC, PM_{10}, $PM_{2.5}$)
3B4a, 3B2, 3B4d, 3B4e, 3B4f	Buffalo, Sheep, Goats, Horses, Mules and Asses	T1 (NH_3, NOx, NMVOC, PM_{10}, $PM_{2.5}$)	NS, IS	CS (NH_3), D (NMVOC, NOx, PM_{10}, $PM_{2.5}$)
3B3	Swine	T2 (NH_3), T1 (NOx, NMVOC, PM_{10}, $PM_{2.5}$)	NS	CS (NH_3), D (NMVOC, NOx, PM_{10}, $PM_{2.5}$)
3B4gi, 3B4gii, 3B4giv	Poultry	T2 (NH_3), T1 (NOx, NMVOC, PM_{10}, $PM_{2.5}$)	AS	CS (NH_3), D (NMVOC, NOx, PM_{10}, $PM_{2.5}$)
3B4h	Other	T1 (NH_3, NOx)	NS	CS (NH_3), D (NOx)

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. 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*.

The excretion rates (CRPA, 2006[a]; GU, 2006; Xiccato *et al*., 2005), slurry/solid manure production and average weights (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, 2006 [a], [b], CRPA, 2010[b]). 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 2015*

Category	Weight	Housing	Grazing	Total
	kg	*kg head^{-1} yr^{-1}*		
Non-dairy cattle	381.5	49.55	1.42	**50.97**
Dairy cattle	602.7	110.20	5.80	**116.00**
Buffalo	510.5	89.22	2.66	**91.89**
Other swine (*)	88.3	13.48	-	**13.48**
Sow (*)	172.1	28.31	-	**28.31**
Sheep	47.0	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	1.7	0.50	-	**0.50**
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

Activity data of swine population (3B3) reported in the IIR/NFR are different from data reported in the NIR/CRF. In fact, piglets (swine less than 20 kg) are included in the swine population in the NIR/CRF for the estimation of CH_4 emission from enteric fermentation, while they are not included in the number of the NFR templates because the NH_3 EF used for sows 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 6.5.

Table 6.5 *Abatement technologies for the swine category*

	1990	2003	2005
Livestock category		**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
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
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
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
		Storage	
fattening swine	60% lagoons; 35% tanks; 5% covered storage	50% lagoons; 40% tanks; 10% covered storage	46% lagoons; 51% tanks; 3% covered storage
sows	60% lagoons; 35% tanks; 5% covered storage	50% lagoons; 40% tanks; 10% covered storage	46% lagoons; 51% tanks; 3% covered storage
		Land spreading	
swine	100%	80% broadcasting 10% low efficiency 10% high efficiency	78% broadcasting 11% low efficiency 11% high efficiency

As regards 3B4gi (laying hens) and 3B4gii (Broilers) categories, NH_3 emissions show different trends. The different trend for the laying hens category 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. As regards broilers, only a slight improvement on spreading system has occurred. The abatement technologies considered for the laying hens category are referred to the years 1990, 2003 and 2005 and are shown in Table 6.6. From 1995 a chicken-dung drying process system has been introduced for laying hens and improved along the period.

Table 6.6 *Abatement technologies for the laying hens category*

	1990	2003	2005
Type of manure		**Housing**	
liquid manure	100%	20 % vertical tiered cages	11% cage system open manure storage under the cages
solid manure		24% deep pit 56% manure belts and forced air drying	74% cage system manure belt with forced air drying 2% cage system manure belt with whisk-forced air drying 10% cage system aerated open manure storage (deep pit system) 3% cage system manure belt with drying tunnel over the cages
		Storage	
liquid manure	100%	20%	11%
solid manure		80%	89%
		Land spreading	
liquid manure	100%	1% broadcasting 10% low efficiency 9% high efficiency	1% broadcasting 7% low efficiency 3% high efficiency
solid manure		8% broadcasting 32% low efficiency 40% high efficiency	8% broadcasting 33% low efficiency 48% high efficiency

Regarding emission factors for swine, poultry and 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]).

Average emission factors for NH_3 per head are reported in Table 6.7.

Table 6.7 *NH_3 emission factors for manure management for the year 2015*

Category	Housing	Storage	Land spreading	Total
			kg NH_3 head^{-1} yr^{-1}	
Non-dairy cattle	6.95	9.35	5.67	**21.97**
Dairy cattle	15.46	20.36	12.65	**48.47**
Buffalo	12.52	16.49	12.10	**41.10**
Other swine (*)	2.38	2.19	1.46	**6.04**
Sow (*)	4.86	4.62	3.09	**12.57**
Sheep	0.22		0.46	**0.68**
Goats	0.22		0.46	**0.68**
Horses	3.24		2.75	**5.99**
Mules and asses	3.24		2.75	**5.99**
Laying hens	0.09	0.06	0.04	**0.19**
Broilers	0.08	0.05	0.03	**0.15**
Other poultry	0.18	0.11	0.06	**0.35**
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

For NO_X emissions (during housing and storage) a tier 1 method was used for calculations. EFs by livestock category and manure type derived from the EMEP/EEA Guidebook (EMEP/EEA, 2013) are constant for the whole time series for the different livestock categories.

For NMVOC emissions a tier 1 method was used for calculations. EFs used are constant for the whole time series for the different livestock categories. NMVOC EFs are those included in the US EPA AP 42 Compilation of Air Pollutant Emission Factors Guidebook (http://www.epa.gov/ttn/chief/ap42/index.html).

For particulate matter emissions a tier 1 method was used for calculations. EFs for PM_{10} and $PM_{2.5}$ are derived from the EMEP/EEA Guidebook (EMEP/EEA, 2016; 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 new factors from 2005, reflecting changes in manure management systems recorded by ISTAT surveys (FSS and the agricultural census). In the current submission, 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 6.8.

Table 6.8 *PM emission factors for manure management for the year 2015*

Category	**PM_{10}**	**$PM_{2.5}$**
	kg PM head^{-1} yr^{-1}	
Non-dairy cattle	0.315	0.208
Dairy cattle	0.592	0.386
Buffalo	0.484	0.317
Other swine (*)	0.190	0.008
Sow (*)	0.225	0.011
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
Other poultry	0.053	0.010
Rabbit	-	-
Fur animals	0.053	0.002

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

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. 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, which provides different EFs by type of fertilizers taking into account climatic conditions (EFs in Table 6.2). A tier1/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. 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). NO_X emission factor is 0.7% of the N content (EMEP/CORINAIR, 2006)

The method for estimating NH_3 emissions from animal manure applied to soils (3Da2a) is described in 3B (tier 2). The default NO_X EF is from EMEP/EEA Guidebook (EMEP/EEA, 2013).

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 6.9, the total amount of sewage sludge production as well as sludge used in agriculture and nitrogen content in sludge is reported.

The volatilization factor for $N\text{-}NH_3$+NO_X emissions is 20% (IPCC, 2006), whereas 16% is emitted as $N\text{-}NH_3$ and 4% as $N\text{-}NO_X$.

Table 6.9 *Sludge spreading activity data and parameters, 1990 – 2015*

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	3,402,016	869,696	217,424	5.0	10,954
2005	4,298,576	862,970	215,742	4.1	8,874
2010	3,358,900	992,859	248,215	4.0	10,040
2011	3,407,040	1,196,634	299,159	3.7	11,119
2012	2,616,094	1,096,380	274,095	4.7	12,864
2013	2,237,073	944,450	236,113	4.0	9,445
2014	2,493,747	1,060,521	265,130	4.0	10,605
2015	2,539,088	1,087,652	271,913	4.0	10,877

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 the paragraph 6.1). The volatilization factor for $N\text{-}NH_3$+ NO_X emissions is 20% (IPCC, 2006), whereas 16% is emitted as $N\text{-}NH_3$ and 4% as N- NO_X.

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, 2013).

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 NH_3/ha (EMEP/CORINAIR, 2006). In Table 6.10, cultivated surface from N-fixing species (ha yr^{-1}) and N fixed by each species (kg N ha^{-1} yr^{-1}) are shown.

Table 6.10 *Cultivated surface (ha) and nitrogen fixed by each variety (kg N ha^{-1} yr^{-1})*

	N fixed	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	(kg N $ha^{-1}yr^{-1}$)					(ha)					
Broad bean , f,s.	40	16,564	14,180	11,998	9,484	8,487	7,440	6,515	9,235	8,484	7,914
Broad bean, d.s.	40	104,045	63,257	47,841	48,507	52,108	43,477	46,130	42,584	41,074	42,157
Pea, f,s.	50	28,192	21,582	11,403	11,636	8,691	24,026	15,283	14,190	15,821	14,940

	N fixed	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Pea, d.s.	72	10,127	6,625	4,498	11,134	11,692	10,770	9,861	9,458	9,970	11,181
Chickpea	40	4,624	3,023	3,996	5,256	6,813	5,830	7,928	8,259	9,037	11,167
Lentil	40	1,048	1,038	1,016	1,786	2,458	2,156	2,629	2,643	2,463	3,099
Vetch	80	5,768	6,532	6,800	7,656	8,000	8,000	8,200	8,200	8,200	8,230
Lupin	40	3,303	3,070	3,300	2,500	4,000	4,000	5,000	5,000	5,000	4,620
Soya bean	58	521,169	195,191	256,647	152,331	159,511	165,955	152,993	184,146	232,867	308,979
Alfalfa	194	987,000	823,834	810,866	779,430	745,128	728,034	599,031	708,208	699,296	667,325
Clover grass	103	224,087	125,009	114,844	103,677	102,691	101,819	86,976	108,310	115,902	119,942
Total		**1,958,025**	**1,301,746**	**1,307,702**	**1,165,298**	**1,135,606**	**1,128,033**	**963,956**	**1,125,191**	**1,169,608**	**1,222,483**

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

HCB emissions from the use of pesticides (3Df) have been estimated. The category is key category at level assessment in 1990 and trend assessment. HCB emissions result from the use of HCB as pesticide but also by the use of other pesticides which contain HCB as an impurity.

The availability of data allows estimating emissions from pesticides where HCB is found as an impurity, as in lindane, DCPA, clorotalonil and Picloram. Emissions from the use of HCB as a pesticide were not estimated. On the basis of the amount of HCB contained in these pesticides (lindane: 0.01%; DCPA: 0.1%; clorotalonil: 0.005%; Picloram: 0.005%) and applying the HCB emission factor provided from the EMEP/EEA Guidebook, HCB emissions result in 23 kg for 1990 and 0.39 kg in 2013 for Italy. An international research work at European level (Berdowski et al., 1997) estimated 400kg 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 is shown in Table 6.11.

Table 6.11 *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)	T1/T2 (NH_3), T1 (NO_X)	NS	D (NH_3, NO_X)
3Da2a	Animal manure applied to soils	T1/T2 (NH_3), T1 (NO_X)	NS	CS (NH_3), D (NO_X)
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)	NS	CS (NH_3)
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	-	-	-
3Dd	Off-farm storage, handling and transport of bulk agricultural products	-	-	-
3De	Cultivated crops	CS (NH_3)	NS	D (NH_3)
3Df	Use of pesticides	T1 (HCB)	NS	D (HCB)

Field burning of agricultural residues (3F)

NMVOC, CO, NO_X, PM_{10}, $PM_{2.5}$ and BC emissions have been estimated, applying the tier 1 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 PM_{10} and $PM_{2.5}$ emission factors from the USEPA (EPA, 1995) and BC emission factors from the EMEP/EEA Guidebook (EMEP/EEA, 2013) have been applied.

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, 2016).

As concerns PM emission factors, values used are lower than those (both tier 1 and tier 2) reported in the EMEP/EEA Guidebook (EMEP/EEA, 2016). 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 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.

6.3 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 2015 the sector accounts for:

- 96.1% of national total NH_3 emissions
- 7.2% of national total PM_{10} emissions
- 3.1% of national total $PM_{2.5}$ emissions
- 3.2% of national total NO_X emissions and
- 1.9% of national total HCB emissions

Moreover, the sector comprises 0.5% of total CO emissions, 0.5% of BC and 0.1% of NMVOC. There are no particular differences as compared to the sectoral share in 1990 when the agriculture sector accounted for 97.8% of NH_3 emissions, 7.4% of PM_{10}, 2.9% of $PM_{2.5}$, 1.2% of NO_X, except for HCB emissions where agriculture accounted for 54.2% of total national emissions.

Table 6.12 reports the key categories identified in the agriculture sector while the time series of NH_3 emissions by sources is shown in Table 6.13.

Concerning NH_3 emissions, the category *manure management (3B*) represents, in 2015, 55.8% of national total ammonia emissions (57.0% in 1990). In particular, NH_3 emissions from *cattle* (3B1) stand for 59.2% of 3B emissions, while emissions from *swine* (3B3) and *poultry* (3B4g) represent 16.5% and 14.3%, respectively. The category *agricultural soils (3D*) represents, in 2015, 40.3% of national total ammonia emissions (40.8% in 1990). The animal manure applied to soils (3Da2a) and the use of synthetic N-fertilisers (3Da1) represent 47.3% and 37.5% of 3D emissions, respectively.

Regarding PM_{10} emissions, the category *manure management (3B*) accounts for 5.9% in 2015 (6.6% in 1990) of national total PM_{10} emissions. *Poultry* (3B4g), *cattle* (3B1) and *swine* (3B3) represent the major contributors to the total PM_{10} emissions from category 3B with 57.8%, 22.0% and 13.3%, respectively. For $PM_{2.5}$ emissions, the category *manure management* (3B) contributes for 1.7% in 2015 (2.0% in 1990) of national total $PM_{2.5}$ emissions. *Cattle* (3B1) accounts for 57.9%, while *poultry* (3B4g) stands for 28.0% to the total $PM_{2.5}$ emissions from category 3B.

For NO_X emissions, the category *agricultural soils* (3D) contributes for 3.0% in 2015 (1.1% in 1990). *Inorganic N-fertilizers* (3Da1) and *Other organic fertilisers applied to soils* (3Da2c) account for 52.2% and 35.0% of total 3D emissions, respectively.

Table 6.12 *Key categories in the agriculture sector in 2015*

	SO_X	NO_X	NH3	NMVOC	CO	PM10	PM2.5	BC	Pb	Cd	Hg	PAH	DIOX	HCB	PCB
							%								
3B1a		0.03	16.63	0.01		0.60	0.44								
3B1b		0.04	16.39	0.03		0.70	0.51								
3B2		0.01	0.40	0.00		0.21	0.07								
3B3		0.00	9.19	0.02		0.78	0.04								
3B4a		0.00	2.76	0.00		0.10	0.07								

	SO$_X$	NO$_X$	NH3	NMVOC	CO	PM10	PM2.5	BC	Pb	Cd	Hg	PAH	DIOX	HCB	PCB
							%								
3B4d		0.00	0.05	0.00		0.03	0.01								
3B4e		0.01	0.32	0.00		0.05	0.04								
3B4f		0.00	0.06	0.00		0.01	0.00								
3B4gi		0.02	1.41			0.69	0.06								
3B4gii		0.02	3.93			1.64	0.18								
3B4giv		0.04	2.66			1.08	0.22								
3B4h		0.00	1.98			0.01	0.00								
3Da1		1.56	15.10												
3Da2a		0.15	19.07												
3Da2b		0.19	0.54												
3Da2c		1.05	3.00												
3Da3		0.04	2.22												
3De			0.38												
3Df															
3F		0.06		0.07	0.54	1.25	1.40	0.49						1.94	

Note: key categories are shaded in blue

Table 6.13 *Time series of ammonia emissions in agriculture (Gg)*

NFR SECTOR 3	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
3B1a Manure management - Dairy cattle	98.29	76.27	74.63	65.98	62.54	62.86	66.52	66.70	65.58	65.42
3B1b Manure management - Non-dairy cattle	84.81	84.71	80.63	70.37	65.25	65.66	64.11	65.45	63.98	64.46
3B2 Manure management - Sheep	1.91	2.33	2.42	1.74	1.73	1.74	1.53	1.57	1.57	1.56
3B3 Manure management - Swine	36.21	34.34	34.60	36.97	37.40	37.52	36.53	35.60	36.11	36.16
3B4a Manure management - Buffalo	2.92	4.45	5.58	6.17	10.98	10.64	10.06	11.55	10.93	10.86
3B4d Manure management - Goats	0.28	0.30	0.30	0.21	0.21	0.21	0.19	0.21	0.20	0.21
3B4e Manure management - Horses	0.93	1.02	0.91	0.90	1.21	1.21	1.28	1.28	1.27	1.25
3B4f Manure management - Mules and asses	0.27	0.12	0.11	0.10	0.15	0.17	0.19	0.20	0.22	0.23
3B4gi Manure management - Laying hens	13.87	12.68	9.56	7.69	7.64	7.75	6.22	5.53	5.39	5.53
3B4gii Manure management - Broilers	12.37	12.96	12.17	12.33	13.80	14.08	15.03	15.18	15.18	15.47
3B4giv Manure management - Other poultry	9.05	11.30	10.33	11.12	10.68	10.51	10.79	10.54	10.39	10.48
3B4h Manure management - Other animals (*)	7.51	8.41	8.79	10.00	8.69	8.54	8.51	8.08	8.03	7.79
3Da1 Inorganic N-fertilizers (includes also urea application)	73.44	79.63	78.60	77.11	52.44	54.28	79.35	64.27	57.52	59.38
3Da2a Animal manure applied to soils	101.94	90.35	84.74	75.69	75.17	75.42	75.41	76.04	74.86	75.00
3Da2b Sewage sludge applied to soils	0.99	1.58	2.13	1.72	1.95	2.16	2.50	1.83	2.06	2.11
3Da2c Other organic fertilisers applied to soils (including compost)	2.95	3.26	4.39	4.76	8.42	20.09	9.90	11.64	14.81	11.81
3Da3 Urine and dung deposited by grazing animals	10.23	11.36	11.58	8.83	9.11	9.14	8.61	8.82	8.75	8.74
3De Cultivated crops	2.38	1.58	1.59	1.42	1.38	1.37	1.17	1.37	1.42	1.48
Total	**460.34**	**436.67**	**423.04**	**393.08**	**368.75**	**383.33**	**397.91**	**385.85**	**378.27**	**377.94**

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 2015 total NH_3 emissions from 3B have reduced by 18.3%. Cattle livestock decreased by

25.4% (from 7,752,152 to 5,781,348 heads). Dairy cattle and non-dairy cattle have decreased by 30.9% and 22.6%, respectively. The so-called first pillar of the EU Common Agriculture Policy (CAP), dealing with market support, had a strong impact through the milk quota system by reducing animal numbers in the dairy sector to compensate for increasing animal productivity (EEA, 2016). On the contrary, swine and poultry have increased between 1990 and 2015 by 4.6% and 13.3%, 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 1990-2015 emissions have decreased by 26.4% and 19.2% mainly due to the reduction of the number of animals and the use of inorganic N-fertilizers, that are decreased overall by 45.6% (although the urea decreased by 8.6%). 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. In the last years, as a consequence of 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, 2008; ISPRA, 2009; ISPRA, several years [c]; ISPRA, several years [d]). The disaggregation of 2010 agricultural emissions has also been finalised and figures are available at the following web site: http://www.sinanet.isprambiente.it/it/inventaria/disaggregazione_prov2005/disagreggazione%202010/view. The disaggregation (NUTS3) of the NH_3 agricultural emissions is shown in Figure 6.2. In 2010, four regions contributed with more than 60% of agricultural NH_3 emissions: Lombardia, Veneto, Emilia Romagna and Piemonte.

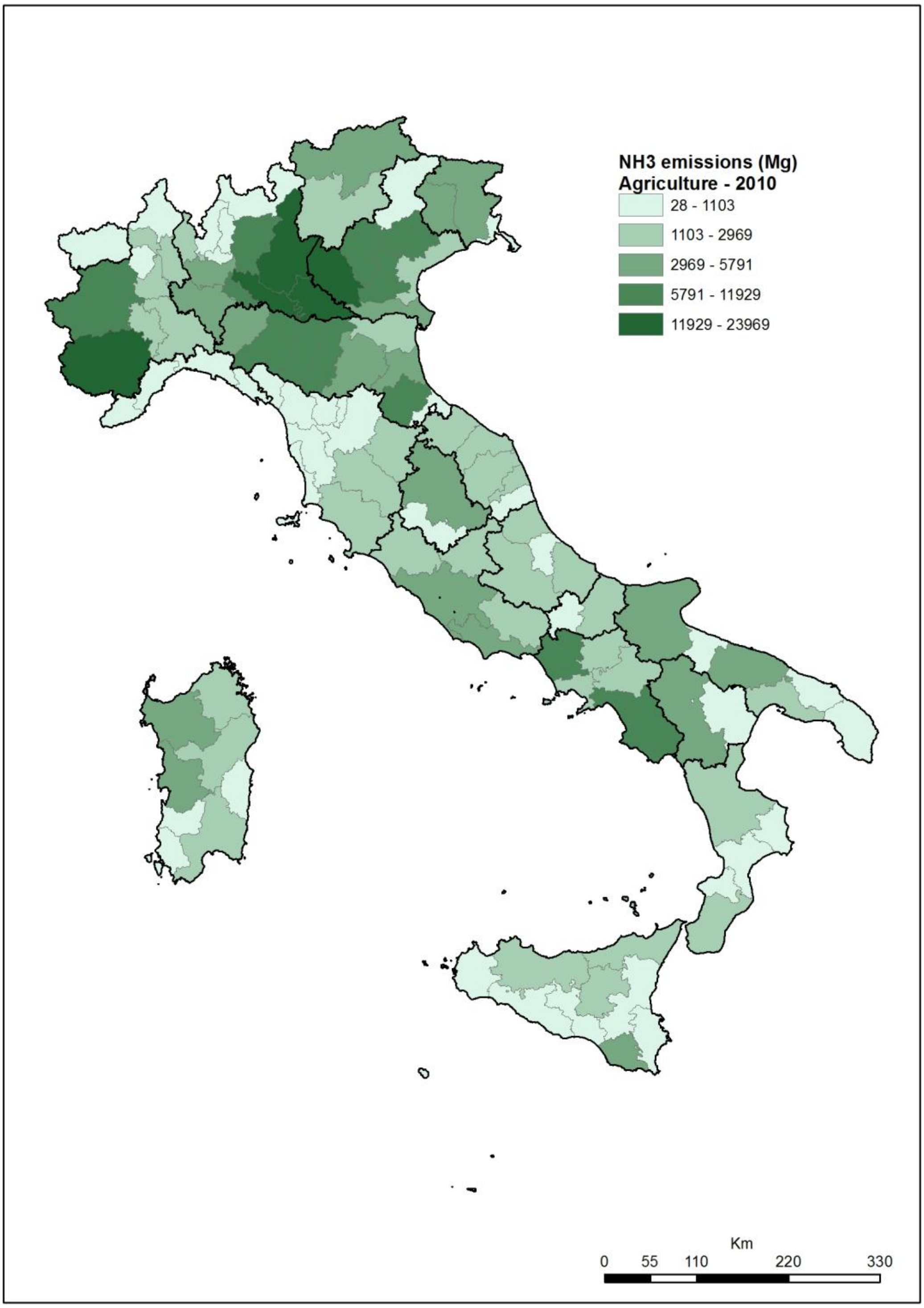

Figure 6.2 *NH_3 emissions from Agriculture in 2010 (t)*

6.4 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 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, 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.

Average NH_3 emission factors for manure management from animal housing have been estimated, for each animal category, on the basis of animal housing collected by the 2010 Agricultural Census. Comparing the obtained values against the country specific parameters, used in the estimation process, slight deviations result, mainly due to the different level of aggregation.

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*[3] (personal communication) for the period 2012-2015 have been compared to official statistics provided by ISTAT and used to estimate the F_{SN} amount. 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 2013-2015. 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.

6.5 Recalculations

In 2017, recalculations were implemented for the agricultural emission inventory.

PM emissions have been updated on the basis of the new emission factors for the manure management category (3B) reported in the last version of the EMEP/EEA Guidebook (EMEP/EEA, 2016).

The percentage distribution between liquid and solid manure of the category Other cattle has been corrected for all time series (changes in NOx and PM emissions – 3B).

NO_X emissions from housing and storage for rabbit have been considered (slight increase in 3B).

The number of fur animals has been update for the period 2012-2014 (slight changes in NH3, NOx and NMVOC emissions – 3B and 3D).

Minor variations of NH_3 emissions (3D) for the period 1990-2014 is due to the update of the NH_3 emission factor for leguminous cultivation (3De), where the new one is taken from the 2007 EMEP/CORINAIR Guidebook[4] (EMEP/CORINAIR, 2007), and the update of activity data relative to the vetch and lupine cultivated surface (only for the year 2014).

Updating data on rice production for the year 2014 involves a slight increase in NOx, NMVOC, CO, PM and BC emissions (3F).

6.6 Planned improvements

Since the 2006 submission, results from a specific project on Mediterranean area, the *MeditAIRaneo Agriculture* project, have been included in the preparation of the UNFCCC/UNECE-CLRTAP agricultural emission inventory (CRPA, 2006[a]). Moreover, outcomes from the convention signed between APAT (now

---

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

[4] In the latest versions of the Guidebook, emission factor is no longer reported.

ISPRA) and the Ministry for the Environment, Land and Sea on NH_3 emission scenarios have been incorporated to the agricultural emissions inventory (CRPA, 2006 [a], [b]; ENEA, 2006, CRPA, 2010[b]).

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*, 3Dc *Farm-level agricultural operations including storage, handling and transport of agricultural products* 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.

The *ad hoc "*Survey on Agricultural Production Methods" (SAPM) regulated by the EU will be crucial for improving the preparation of the agricultural emission inventory. In Italy, this survey was carried out during the 2010 General Agricultural Census; analysis of census data is on progress. Information such as animal grazing period, animal housing, storage systems characteristics, and the use of manure/slurry for land application have been collected. Some information at NUTS3 level (Italian provinces) has been already collected with the incorporation of specific queries in the Farm Structure Survey (FSS) from 2005 and 2007. Information on housing and storage systems, respectively, was analysed and will be validated with information that will be obtained from the 2010 Agricultural Census (CRPA, 2010[a]) and from the 2013 FSS. In the coming years, specific surveys or the inclusion of specific queries on already existing surveys such as Farm Structure Survey (FSS) or Farm Accounting Data Network (FADN) will provide valuable information on animal and agronomic production methods.

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. Under category 5D, no emissions are reported as only CH_4 and N_2O occurred, but following the encouragements derived from the review process NMVOC emissions from wastewater treatment plants are under investigations. Conversely, Italy does not consider NH_3 emissions from latrines because this activity does not occur or it can be considered negligible. In the framework of the Urban Wastewater Treatment Directive (UWWTD, 2011) regarding agglomerations ≥ 2,000 p.e. (population equivalent) and referred to reporting year 2007, Italy reported the following data: 3,246 agglomerations ≥ 2,000 p.e. and 97.8% of all agglomerations have a collecting system in place; in unsewered areas, onsite systems, such as Imhoff tanks, must be used. 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 Biogas production
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

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
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
SO_x			x	x	x	x	x		x
NH_3	x	x							
Particulate matter									
TSP			x	x	x	x	x	x	x
PM10			x	x	x	x	x	x	x
PM2.5			x	x	x	x	x	x	x
BC			x	x	x	x	x	x	x
Priority heavy metals									
Pb			x	x	x	x	x		x
Cd			x	x	x	x	x		x

Main pollutants	5A	5B	5C1a	5C1bi	5C1bii	5C1biii	5C1biv	5C2	5C1bv
Hg			x	x	x	x	x		x
POPs Annex II									
PCB			x	x		x	x		x
POPs Annex III									
Dioxins			x	x	x	x	x	x	x
PAH			x	x	x	x	x	x	x
HCB			x	x		x	x		x
Other heavy metals									
As			x	x	x	x	x		x
Cr			x	x	x	x	x		x
Cu			x	x	x	x	x		x
Ni			x	x	x	x	x		x
Se			x	x		x			x
Zn			x	x	x		x		x

In 2015, *sewage sludge incineration* (5C1b iv), is key category for HCB emissions. In 1990, *industrial waste incineration* (5C1b i) and *municipal waste incineration* (5C1a) are key categories for dioxins emissions whereas *sewage sludge incineration* (5C1b iv) is key category for HCB. As regard the trend, *industrial waste incineration* (5C1b i) and *municipal waste incineration* (5C1a) are key categories for dioxins emissions whereas *sewage sludge incineration* (5C1b iv) is key category for HCB.

The waste sector, and in particular Waste incineration (5C), is a source of different pollutants; for the main pollutants, in 2015, the sector accounts for:

- 67.7 % in national total HCB emissions;
- 8.1 % in national total PAH emissions;
- 3.9 % in national total BC emissions;
- 2.8 % in national total Dioxin emissions;
- 2.0% in national total CO emissions.

Moreover, the sector comprises 1.4% of total PM10 and PM2.5 emissions, 1.6% of NH_3, 1.3% of NMVOC, and for what concerns priority heavy metals 1.0% of Cd, .

7.2 Methodological issues

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). 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, 2017 [a]).

Emissions from the landfill gas combustion in landfills flaring are not estimated at the moment: activity data are available but emission factors are under investigation.

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).

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 2015, the non hazardous landfills in Italy disposed 7,819 kt of MSW and 3,222 kt of industrial wastes, as well as 177 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)*

ACTIVITY DATA (Gg)	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
MSW production	22,231	25,780	28,959	31,664	32,479	31,386	29,994	29,573	29,652	29,524
MSW disposed in landfills for non hazardous waste	17,432	22,459	21,917	17,226	15,015	13,206	11,720	10,914	9,332	7,819
Assimilated MSW disposed in landfills for non hazardous waste	2,828	2,978	2,825	2,914	3,508	2,883	2,292	2,512	2,913	3,222
Sludge disposed in managed landfills for non hazardous waste	2,454	1,531	1,326	544	301	292	214	174	184	177
Total Waste to managed landfills for non hazardous waste	16,363	21,897	26,069	20,684	18,825	16,380	14,226	13,600	12,429	11,218
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	18,825	16,380	14,226	13,600	12,429	11,218

Biological treatment of waste (5B)

Under this category, NMVOC and NH_3 emissions from compost production are reported.

The amount of waste treated in composting plants has shown a great increase from 1990 to 2015 (from 283,879 Mg to 7,288,305 Mg).

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).

Waste Incineration (5C1a – 5C1b)

Regarding waste incineration, methodology used for estimating emissions is based on and consistent with the EMEP/CORINAIR Guidebook (EMEP/CORINAIR, 2007).

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. In 2015, about 98% 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.

For PCB and HCB emission factors published on the Guidebook EMEP/EEA (EMEP/CORINAIR, 2007) in the relevant chapters are used, a survey on HCB emission factor from sludge incineration is currently underway.

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.

Table 7.3 *Emission factors for waste incineration*

Air Pollutant	u.m	Municipal 1990-2009	Municipal Since 2010	Industrial	Clinical	Sludge	Oil
NO_x	*kg/t*	1.15	0.62	2	0.603624	3	2
CO	*kg/t*	0.07	0.07	0.56	0.07542	0.6	0.07542
NMVOC	*kg/t*	0.46046	0.46046	7.4	7.4	0.25116	7.4
SO_2	*kg/t*	0.39	0.02	1.28	0.02594	1.28	1.28
PM10	*g/t*	46	6.06	240	25.676	180	240
PM2.5	*g/t*	46	6.06	240	25.676	180	240
BC	*g/t*	1.61	0.21	8.40	0.90	6.30	8.40
As	*g/t*	0.05	0.02	0.12	0.0042	0.5	0.12
Cu	*g/t*	1	0.001	1.2	0.564	10	1.2
Se	*g/t*	0.013	0.013	0.006	0.03736	-	0.006
Zn	*g/t*	0.017	0.017	12.6	-	10	12.6
Cd	*g/t*	0.25	0.01	0.8	0.001128	1.2	0.8
Cr	*g/t*	0.45	0.002	1.6	0.01168	3	1.6
Hg	*g/t*	0.15	0.033	0.8	0.03684	1.2	0.8
Ni	*g/t*	16.35	0.001	0.8	0.02504	3	0.8
Pb	*g/t*	1.35	1.04	24	0.0246	3	24
PAH	*g/t*	0.05	0.00054	0.48	0.00014126	0.6	0.48
PCB	*g/t*	0.005	0.00005	0.005	0.02	0.005	-
HCB	*g/t*	0.001	0.00002	0.0001	0.019	0.500	-

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 2015.

Table 7.4 *Dioxin emission factors for 1990 and 2015*

Waste Typology	u.m	1990	2015
Municipal	μg/t	115 - 1.6	0.1
Clinical	μg/t	200	0.5
Industrial	μg/t	80 - 135	0.5
Sludge	μg/t	77	0.5
Oil	μg/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	2011	2012	2013	2014	2015
					Gg					
Total waste	1,656.2	2,149.1	3,061.7	4,964.2	6,977.3	6,797.3	6,709.4	7,002.5	7,424.5	7,471.5
with energy recovery	911.2	1,557.8	2,749.7	4,720.6	6,795.9	6,614.6	6,517.8	6,794.2	7,306.1	7,353.8
without energy recovery	745.0	591.3	312.0	243.5	181.4	182.7	191.6	208.3	118.3	117.6
Municipal waste (5C1a)	1,025.6	1,436.6	2,324.9	3,219.9	4,336.9	4,733.0	4,256.6	4,314.0	4,711.7	4,698.4
with energy recovery	626.4	1,185.5	2,161.4	3,168.0	4,284.0	4,695.0	4,255.1	4,314.0	4,711.7	4,698.4
without energy recovery	399.2	251.1	163.5	51.9	52.9	38.0	1.5	0.0	0.0	0.0
Industrial waste (5C1b i-ii-iv)	496.1	560.7	626.5	1,618.1	2,505.3	1,961.1	2,334.6	2,590.5	2,614.1	2,675.0
with energy recovery	259.5	331.2	511.6	1,447.0	2,399.4	1,849.0	2,192.5	2,431.2	2,550.2	2,611.5
without energy recovery	236.6	229.6	114.8	171.1	105.9	112.2	142.0	159.3	63.9	63.5
Clinical waste (5C1biii)	134.5	151.7	110.3	126.2	135.1	103.1	118.2	97.9	98.7	98.0
with energy recovery	25.3	41.1	76.7	105.7	112.5	70.6	70.1	49.0	44.2	43.9
without energy recovery	109.2	110.6	33.6	20.5	22.6	32.5	48.1	49.0	54.5	54.1

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, 2009).

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 are those reported in the Guidebook.

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 137,168 in 2015. 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	2011	2012	2013	2014	2015
Cremations	5,809	15,436	30,167	48,196	77,379	87,871	101,842	110,712	118,323	137,168
Deaths	543,700	555,203	560,241	567,304	587,488	593,404	612,883	600,744	598,364	653,000

Cremation of corpses	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Mortal remains	1,000	1,750	1,779	9,880	18,899	23,353	29,009	29,588	30,242	34,178
% of cremation	1.07	2.78	5.38	8.50	13.17	14.81	16.62	18.43	19.77	21.01
Crematoria	ND	31	35	43	53	56	58	63	67	70

Table 7.7 *Emission factors for cremation of corpses*

Air pollutant	u.m.	Cremation
NO_X	kg/body	0.309
CO	kg/body	0.141
NMVOC	kg/body	0.013
SO_X	kg/body	0.544
PM10	g/body	14.6
PM2.5	g/body	14.6
Pb	mg/body	0.0186
Cd	mg/body	0.00311
Hg	mg/body	0.934
As	mg/body	0.011
Cr	mg/body	0.00844
Cu	mg/body	0.00771
Ni	mg/body	0.0107
PAH (benzo(a)pyrene)	μg/body	0.0103
Dioxins	μg/body	0.0168

Small scale waste burning (5C2)

Emissions from burning of agriculture residues burnt off-site are not key categories. Moreover, Dioxins, TSP, PM10, PM2.5, BC, CO, NMVOC, PAH and NO_X emissions have been estimated. No estimations were performed for NH_3 and SO_X emissions as well as HMs and other POPs.

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

1. Amount of removable residues (t), estimated with annual crop production (ISTAT, several years [a], [b]; ISTAT, 2016 [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, the following emission factors have been used to estimate PAH, PM, BC and dioxins (Table 7.8).

Table 7.8 *Emission factors for burning of agriculture residues*

Air pollutant	u.m.	Removable residues	References
PAH	g/t	8.58	TNO, 1995
PM10	g/t	3.3	EMEP/CORINAIR, 2007
PM2.5	g/t	2.8	EMEP/CORINAIR, 2007
Dioxins	µg/t	10	EMEP/CORINAIR, 2007
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, 2014 [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 4.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, PAH and dioxins emission factors as reported in the table above. The amount of biomass from pruning used for domestic heating is reported in the energy sector in the 1A4b category as biomass fuel.

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

Production	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Cereals										
Wheat	8,108.5	7,946.1	7,427.7	7,717.1	6,849.9	6,641.8	7,654.2	7,312.0	7,141.9	7,394.5
Rye	20.8	19.8	10.3	7.9	13.9	14.4	16.1	14.3	11.5	13.2
Barley	1,702.5	1,387.1	1,261.6	1,214.1	944.3	950.9	940.2	875.6	848.7	955.1
Oats	298.4	301.3	317.9	429.2	288.9	297.1	292.4	246.9	241.1	261.4
Rice	1,290.7	1,320.9	1,245.6	1,444.8	1,574.3	1,560.1	1,601.5	1,433.1	1,415.9	1,518.3
Maize	5,863.9	8,454.2	10,139.6	10,427.9	8,495.9	9,752.4	7,888.7	7,899.6	9,250.0	7,073.9
Sorghum	114.2	214.8	215.2	184.9	275.6	299.9	157.8	316.9	368.8	294.2
Woody crops										
Grapes	8,438.0	8,447.7	8,869.5	8,553.6	7,839.7	7,054.7	6,918.0	8,010.4	6,930.8	7,915.0
Olives	912.5	3,323.5	2,810.3	3,774.8	3,117.8	3,168.3	3,017.5	2,940.5	1,913.7	2,732.9
Citrus Orchards	2,868.8	2,607.7	3,100.2	3,518.1	3,820.6	3,434.8	2,925.1	2,720.6	2,705.5	3,151.5

Production	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
					Gg					
Orchards	5,793.5	5,406.6	5,952.2	6,034.5	5,777.3	6,287.3	5,124.8	5,605.9	5,820.2	5,988.8
Carobs	29.2	44.4	38.1	31.7	25.3	44.7	30.8	9.4	31.5	31.5
Total	***35,441.0***	***39,474.0***	***41,388.0***	***43,338.6***	***39,023.4***	***39,506.5***	***36,567.2***	***37,385.3***	***36,679.7***	***37,330.4***

7.3 Time series and key categories

The following Table 7.10 presents an outline of the weight of the different categories for each pollutant in the waste sector for the year 2015. Key categories are those shaded.

Table 7.10 *Key categories in the waste sector in 2015*

	5A	5B1	5C1a	5C1bi	5C1biii	5C1biv	5C1bv	5C2
				%				
SO_x				0.04	0.00	0.04	0.08	
NO_x				0.01	0.00	0.01	0.01	0.26
NH_3	1.53	0.04						
NMVOC	0.88	0.04		0.03	0.05	0.00	0.00	0.28
CO				0.00	0.00	0.00	0.00	2.00
PM_{10}				0.01	0.00	0.00	0.00	1.42
$PM_{2.5}$				0.01	0.00	0.00	0.00	1.36
BC				0.00	0.00	0.00		3.87
Pb				0.36	0.00	0.03	0.00	
Cd				0.49	0.00	0.47	0.00	
Hg				0.38	0.02	0.36	0.00	
PAH				0.02	0.00	0.02	0.00	8.08
Dioxins				0.01	0.01	0.00	0.00	2.74
HCB				0.02	5.16	62.52		
PCB				0.10	0.55	0.06		

Note: key categories are shaded in blue

In addition, dioxins emissions from municipal and industrial waste are key categories at trend assessment. In particular, from 1990 dioxins emissions from waste incineration (5C1) have decreased by about 100% as a consequence of the introduction of more stringent limits of these emissions for incineration plants (see Table 7.4, Figure 7.2 and Figure 7.5).

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 2015 (Figure 7.1, Figure 7.2, Figure 7.3 and Figure 7.4).

It is important to point out that industrial waste incineration is the major source of HCB emissions (63% of the national total), in particular the waste water sludge incineration, 12.46 Kg in 2015, which shows an increase of 20.3% with respect to the reference year (Figure 7.2).

Finally, in Table 7.11, emissions time series for each pollutant of the waste sector are reported. In the period 1990-2015, 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 2015, about 98% of the total amount of waste incinerated is treated in plants with energy recovery system reported in 1A4a.

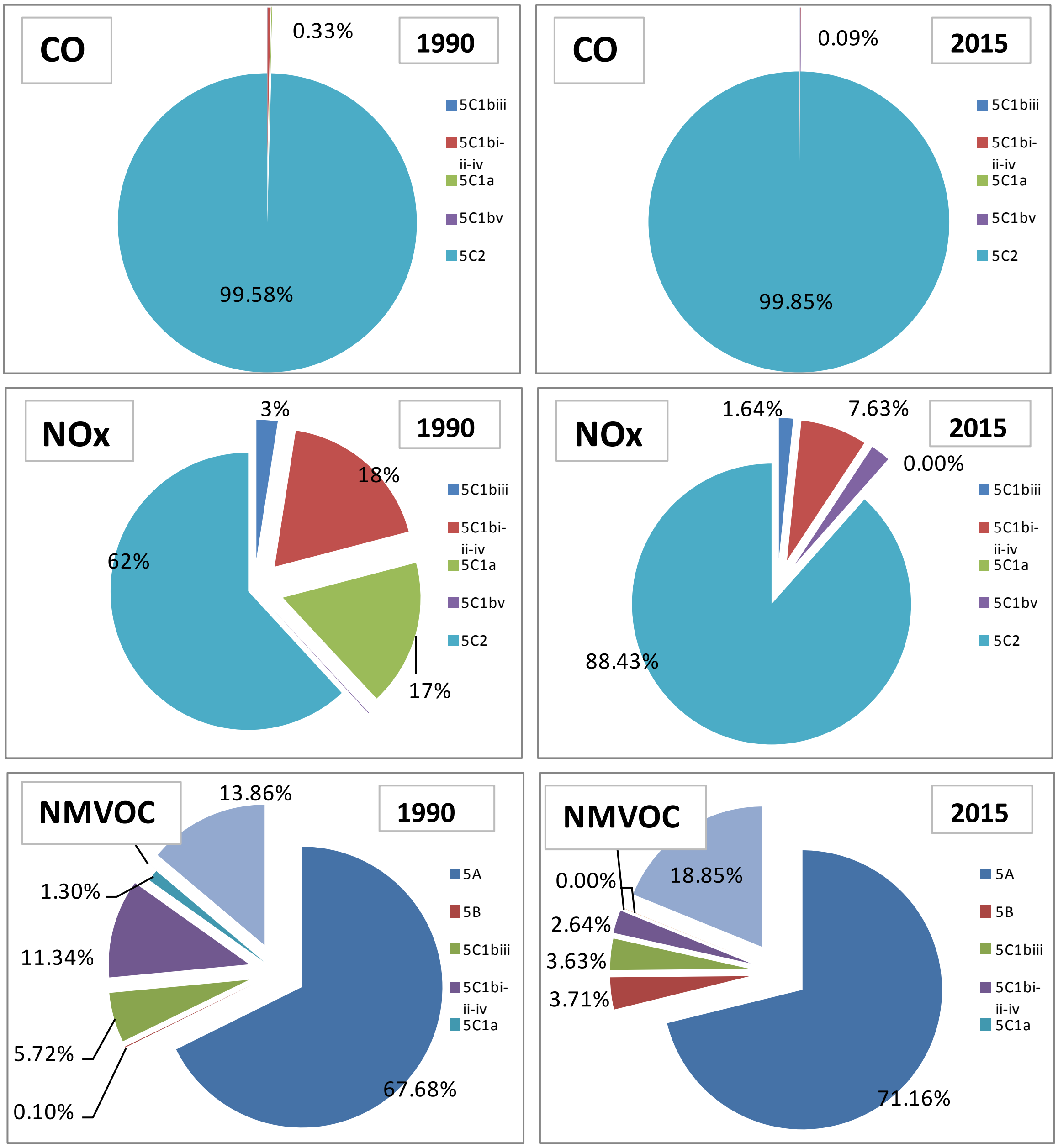

Figure 7.1 *Contribution of CO, NO_X and NMVOC sub-category emissions to waste sector total emissions*

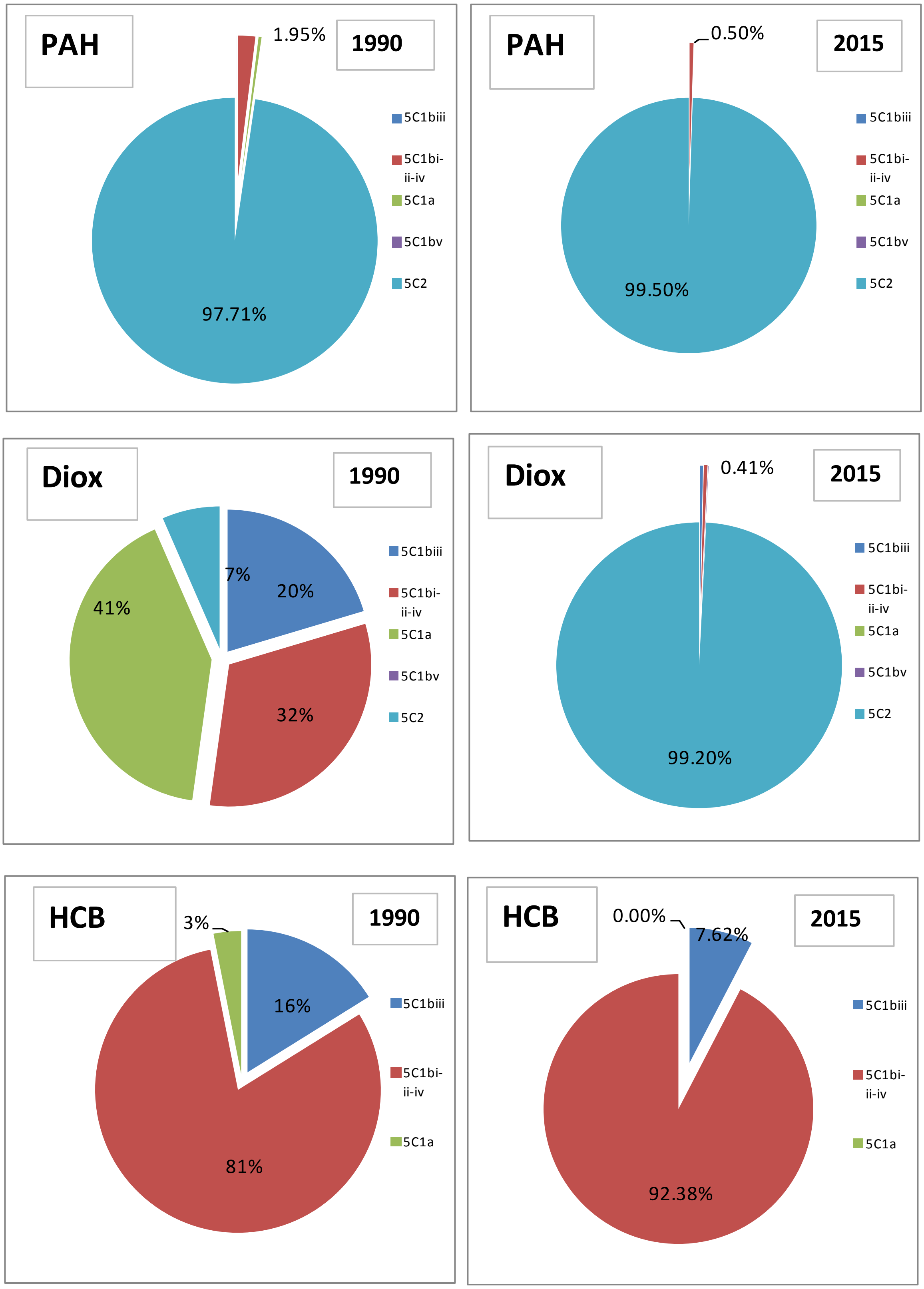

Figure 7.2 *Contribution of POPs Annex III sub-category emissions to waste sector total emissions*

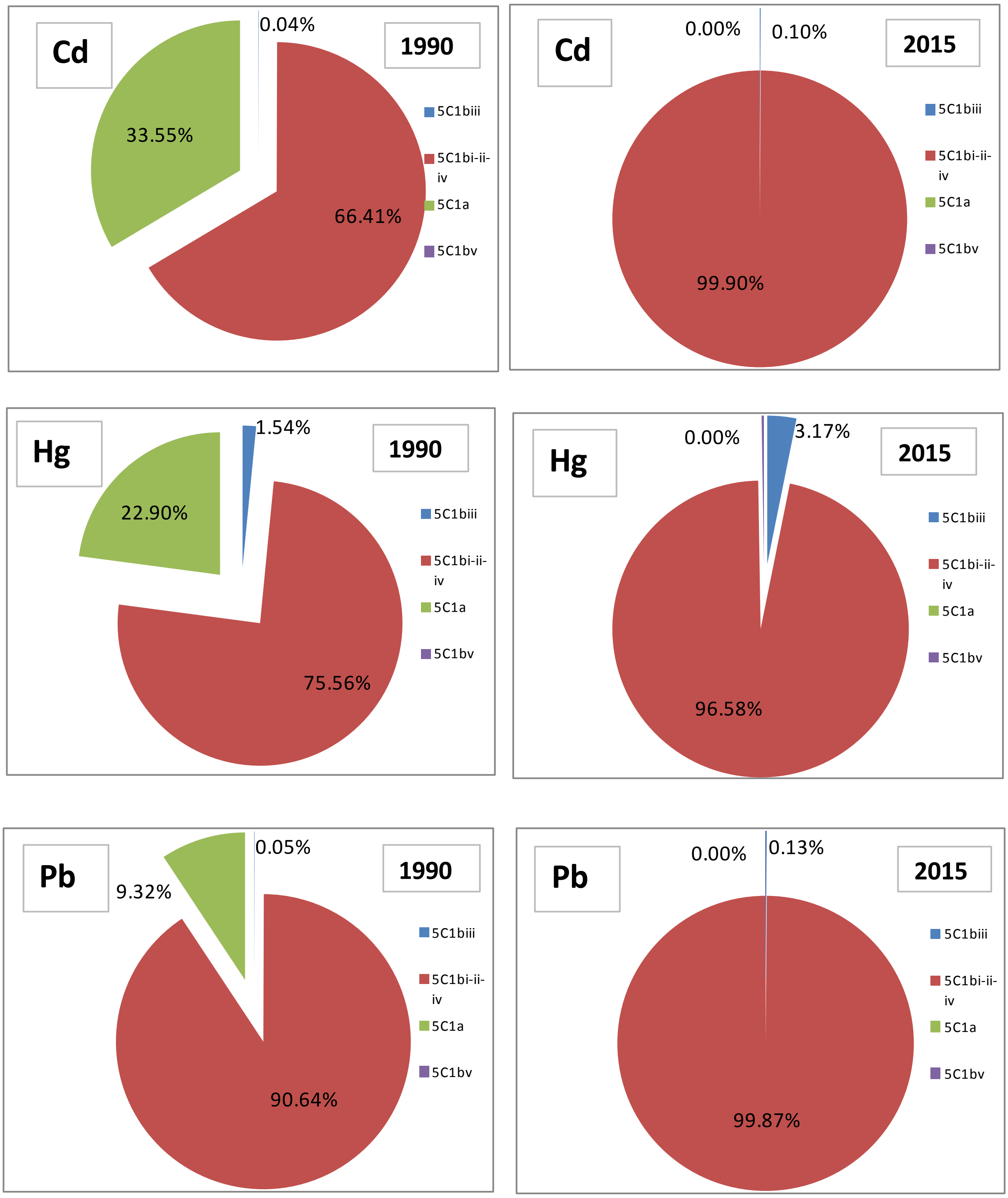

Figure 7.3 *Contribution of priority heavy metals sub-category emissions to waste sector total emissions*

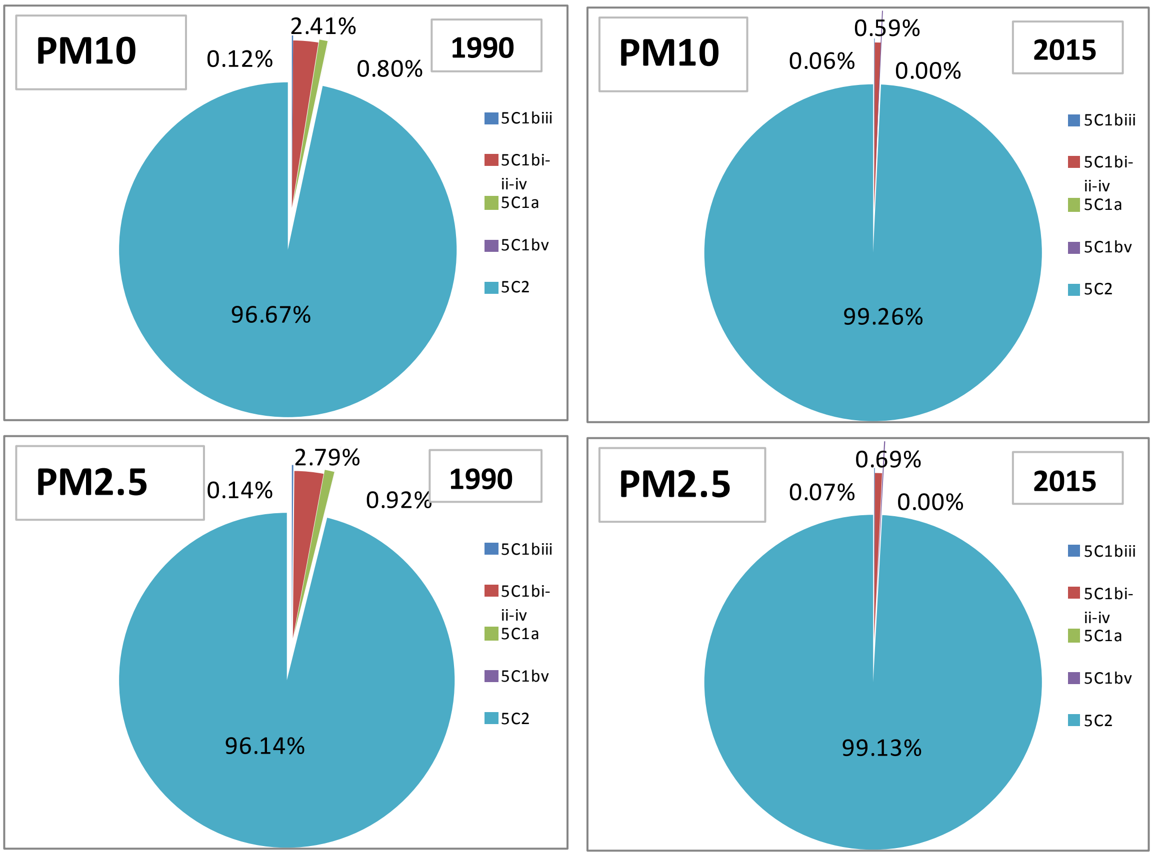

Figure 7.4 *Contribution of PM10 and PM2.5 sub-category emissions to waste sector total emissions*

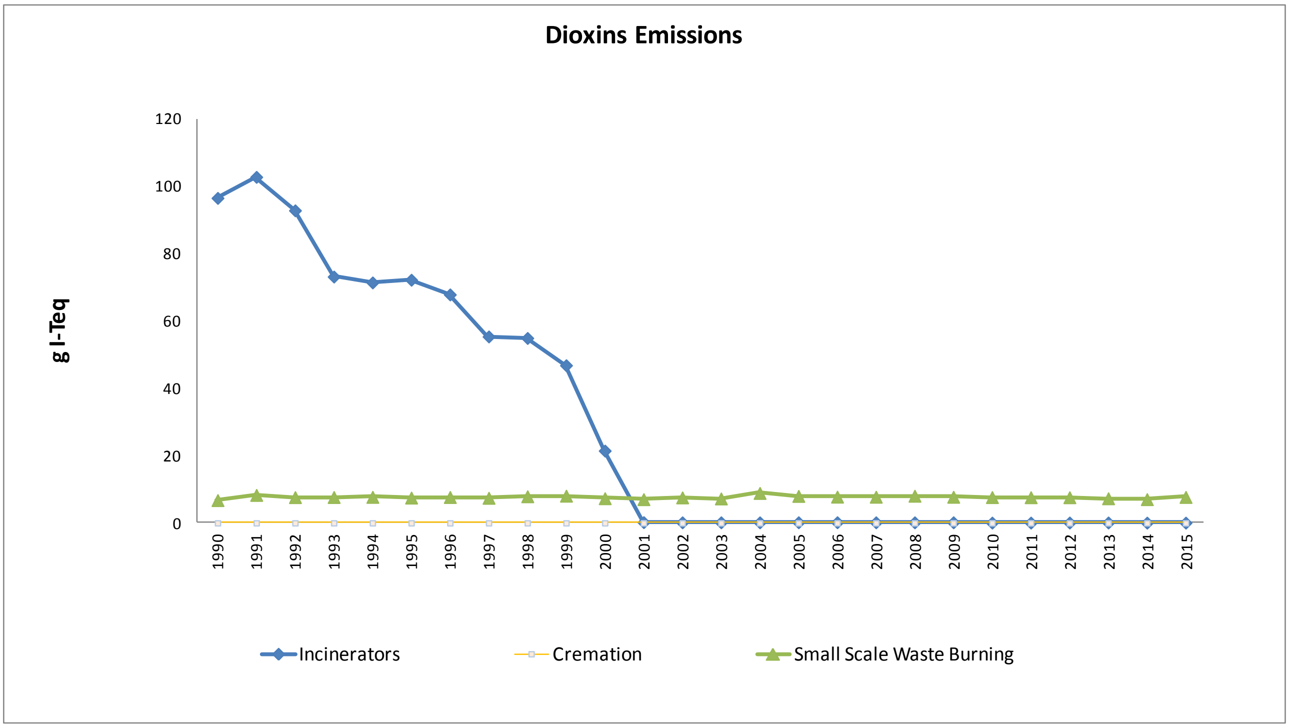

Figure 7.5 *Time series of dioxin emissions of the waste sector by category (g I-Teq)*

Table 7.11 *Time series emissions in the waste sector by category and pollutant*

WASTE SECTOR	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Solid waste disposal (5A)										
NMVOC (Gg)	9.57	8.92	10.22	10.37	9.23	8.93	8.96	8.06	7.90	7.44
NH_3 (Gg)	7.76	7.23	8.28	8.41	7.48	7.24	7.26	6.53	6.41	6.03
Biological treatment of waste (5B)										
NMVOC (Gg)	0.01	0.03	0.14	0.28	0.36	0.36	0.36	0.38	0.41	0.37
NH_3 (Gg)	0.01	0.02	0.07	0.13	0.17	0.17	0.17	0.18	0.19	0.17
Waste incineration (5C)										
CO (Gg)	40.68	46.90	45.38	50.47	47.18	46.79	47.66	44.86	42.03	47.20
NO_x (Gg)	2.68	2.80	2.34	2.55	2.32	2.31	2.35	2.31	2.00	2.21
NMVOC (Gg)	4.55	4.75	3.26	3.78	3.25	3.27	3.52	3.57	2.79	3.01
SO_x (Gg)	0.48	0.42	0.24	0.28	0.21	0.21	0.27	0.29	0.18	0.19
PM10 (Gg)	2.31	2.55	2.45	2.68	2.55	2.54	2.54	2.45	2.34	2.56
PM2.5 (Gg)	1.99	2.19	2.10	2.31	2.19	2.18	2.19	2.10	2.01	2.19
BC (Gg)	0.81	0.89	0.87	0.95	0.91	0.91	0.90	0.87	0.84	0.91
PAH (t)	5.94	6.57	6.34	6.95	6.62	6.59	6.60	6.34	6.08	6.64
Dioxins (g I-Teq))	103.22	79.68	28.76	8.18	7.73	7.69	7.70	7.41	7.10	7.76
HCB (kg)	12.86	13.96	9.87	8.26	3.43	8.81	14.29	13.95	13.58	13.49
PCB (kg)	5.36	4.61	2.06	1.52	0.98	1.21	1.67	1.78	1.41	1.40
As (t)	0.06	0.05	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.02
Cd (t)	0.30	0.26	0.14	0.16	0.09	0.10	0.12	0.14	0.06	0.06
Cr (t)	0.59	0.51	0.28	0.32	0.18	0.20	0.27	0.29	0.14	0.14
Cu (t)	0.93	0.79	0.48	0.41	0.19	0.30	0.43	0.45	0.33	0.33
Hg (t)	0.26	0.23	0.12	0.15	0.09	0.10	0.13	0.14	0.06	0.06
Ni (t)	6.76	4.34	2.81	1.02	0.10	0.13	0.17	0.19	0.11	0.11
Pb (t)	5.78	5.36	2.60	3.85	2.47	2.39	2.85	3.28	1.01	1.00
Se (t)	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zn (t)	2.93	2.84	1.40	2.12	1.32	1.37	1.72	1.94	0.74	0.74

7.4 Recalculations

In the following table the recalculations occurred in the 2017 submission with respect the last year submission are reported at category level for the whole time series

Table 7.12 *Recalculations in the waste sector by category and pollutant*

WASTE SECTOR	1990	1995	2000	2005	2010	2011	2012	2013	2014
Solid waste disposal (5A)									
NMVOC		-10.58%	-9.72%	1.19%	4.92%	5.29%	7.07%	10.26%	11.22%
NH_3		-10.58%	-9.72%	1.19%	4.92%	5.29%	7.07%	10.26%	11.22%
Biological treatment of waste (5B)									
NMVOC									
NH_3									
Waste incineration (5C)									
CO			0.03%	-0.01%	0.01%	-0.02%	-0.01%	-0.01%	0.68%
NO_x			0.03%	-0.01%	0.01%	-0.02%	-0.01%	-0.01%	-8.69%
NMVOC			0.02%	-0.01%	0.01%	-0.01%	-0.01%	-0.01%	-20.18%
SO_x									-42.80%
PM10			0.02%	-0.01%	0.01%	-0.01%	-0.01%	-0.01%	-0.21%
PM2.5			0.02%	-0.01%	0.01%	-0.01%	-0.01%	-0.01%	-0.38%
BC			0.02%	-0.01%	0.01%	-0.01%	-0.01%	-0.01%	0.74%
PAH			0.02%	-0.01%	0.01%	-0.01%	-0.01%	-0.01%	0.02%
Dioxins			0.01%	-0.01%	0.01%	-0.01%	-0.01%	-0.01%	0.13%
HCB									-6.98%
PCB									-24.22%
As									-42.99%
Cd									-57.59%

WASTE SECTOR	1990	1995	2000	2005	2010	2011	2012	2013	2014
Cr									-54.83%
Cu									-29.97%
Hg									-56.74%
Ni									-44.67%
Pb									-70.62%
Se									-17.61%
Zn									-63.55%

According with the discussion during the ESD review about CH_4 emissions from landfills, Italy partially revised the half life values considering the change in the Italian climatic conditions in terms of annual precipitation. The estimated trends of cumulated rainfall from 1951 to 2015 are decreasing (ISPRA, several years [b]; http://www.scia.isprambiente.it/Documentazione/RAPPORTOCLIMA2015.pdf), above all in the south of Italy where waste management is still largely carried out using landfills. Less precipitation means higher half life values and different distribution of emissions in time. Consequently, emissions of NMVOC and NH_3 undergo a recalculation decreasing by 10.6% in 1992 and increasing by 11.2% in 2014.

About biological treatment, no recalculations occurred.

As regards incineration, recalculations occurred from 1998 because of the update of orchards activity data and the consequent change in the emissions from burning of agriculture residues. Changes from 2011 have been due to the update of activity data supplied by waste incinerators too.

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 flaring of exceeding biogas in landfills and wastewater treatment plants are under investigation and will be included in further submissions.

Following the encouragement derived from the review process NMVOC emissions from wastewater treatment plants are under investigations.

As regards incineration, a survey on HCB emission factor from sludge incineration is ongoing as well as further investigation on emission factors from cremation collecting the relevant data at plant level.

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 2015 have been submitted. The percentage difference between the time series reported in the 2016 submission and the series reported this year (2017 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 2014 show a decrease for some pollutants and an increase for others; in particular a significant decrease of HCB emissions, equal to 4.6%, is due to the update of activity data for sludge incineration with and without energy recovery, the decrease of PM10 and PM2.5 of 4.8% and 1.7% respectively is due to the updates of emission factors for manure management, and the decrease of NMVOC and CO of 3.4% and 3.6% respectively are due to the update of emission factors for off-road machinery because of the application of the relevant European Directives. For the other pollutants recalculations for 2014 are less than 1%.

In 2017 a recalculation which involves both the *energy* and the *waste* sector is related to the update of activity data from 2011 for some industrial waste incineration plant and 2014 for urban waste used in incinerators with and without energy recovery. Recalculations involved especially HMs and POPs and resulted in an increase of emission levels. Main changes for 2014 regarded HCB emissions due to the update of the amount of sludge incineration resulting in the decrease of total HCB emissions for that year.

In the *energy* sector a further revision of the emission estimates regarded the road transport sector. Specifically, the upgraded version of COPERT model, version 11.4 (EMISIA SA, 2016), has been applied to calculate emissions of all pollutants for the whole period 1990-2015. It resulted in a recalculation of the time series for all the pollutants. The complete time series, from 1990 to 2014, of liquid and solid fuel consumptions, for road transport (1.A.3.b), off-road vehicles (1.A.3.c, 1.A.3.d, 1.A.4.b ii, 1.A.4.c) and heating system categories for stationary combustion (1.A.4.a i and 1.A.4.b i), have been updated on the basis of figures submitted by the Ministry of Economic Development to the Joint Questionnaire IEA/OECD/EUROSTAT resulting in recalculation of both stationary and mobile combustion emissions. Moreover, emission reduction targets established in the 2004/26/EC Directive have been applied affecting emission estimates of railway category (1.A.3.c), recreational craft activities (1.A.3.d), household and gardening mobile machinery (1.A.4.b ii), off-road in agriculture, forestry and fishing (1.A.4.c ii and 1.A.4.c iii), and off-road machinery in industry (1.A.2.g vii) affecting especially NMVOC and CO emissions. Concerning the aviation category (1.A.3.a), an overall assessment and comparison with emission estimates provided for Italy by Eurocontrol lead to the update of both activity data, from 2002, and NO_X, SO_X, CO, and PM emission factors from 2005, and a consequent recalculation of emissions from this category. For the stationary fuel combustion categories, minor update occurred for the last years, in the sector 1A1, 1A2, 1A4, affecting EF and activity data on the basis of new information.

In the *industrial processes* sector, recalculations occurred for NMVOC, for 2014, because of the update of bread production activity data.

For the *solvent* sector the main modification involved category 3C for 2014 with respect to NMVOC emissions, due to the update of some activity data for fat edible and non edible oil extraction. Moreover activity data for paint application in manufacture of automobiles has been updated from 2012.

Minor recalculations were implemented for the *agriculture* sector, due to the update of some activity data, except the revision of PM emission factors for manure management which implies a relevant reduction of

PM emissions in the last years.

In the *waste* sector, in addition to the annual revision that regards incineration plants activity data, recalculations occurred in consideration of the update of some industrial waste incinerators from 2011. As a consequence of the review process CH_4 emissions from landfills, Italy partially revised the half life values considering the change in the Italian climatic conditions in terms of annual precipitation resulting in a recalculation of NMVOC and NH_3 emissions which decreased by 10.6% in 1992 and increased by 11.2% in 2014.

Table 8.1 *Recalculation between 2016 and 2017 submissions*

	SO_X	NO_X	NH_3	NMVOC	CO	PM10	PM2.5	Pb	Hg	Cd	DIOX	PAH	HCB	PCB
						%								
1990	-0.98	-0.94	-0.21	-2.80	-2.54	0.40	-0.23	-1.69	-0.46	-2.55	-0.15	-0.24	-0.01	-0.33
1991	-0.72	-0.60	-0.22	-2.95	-2.93	0.69	0.12	-1.59	-0.33	-1.65	-0.15	-0.29	-0.01	-0.25
1992	-0.68	-0.53	-0.39	-1.54	-1.08	0.58	-0.04	-0.05	-0.35	-1.73	-0.13	-0.30	-0.01	-0.26
1993	-0.60	-0.82	-0.41	-2.30	-1.22	0.26	-0.44	-0.07	-0.27	-1.27	-0.12	-0.25	-0.01	-0.18
1994	-0.48	-0.91	-0.39	-2.44	-1.31	0.29	-0.47	-0.07	-0.23	-1.09	-0.12	-0.29	-0.01	-0.16
1995	-0.44	-0.87	-0.30	-2.69	-1.38	0.49	-0.36	0.25	-0.23	-1.08	-0.12	-0.32	-0.02	-0.15
1996	-0.36	-0.79	-0.24	-2.82	-1.43	0.72	-0.16	0.47	-0.22	-0.99	-0.12	-0.31	-0.01	-0.15
1997	-0.29	-0.86	-0.26	-2.87	-1.50	0.77	-0.18	0.35	-0.22	-0.99	-0.10	-0.25	-0.01	-0.15
1998	0.00	-0.20	-0.20	-2.87	-1.43	1.51	0.62	0.92	0.00	0.02	-0.04	-0.23	-0.01	-0.16
1999	-0.01	-0.54	-0.18	-2.92	-1.55	1.38	0.47	0.74	0.00	0.02	-0.01	-0.09	-0.01	0.01
2000	0.06	-0.57	-0.10	-3.12	-1.68	1.22	0.39	0.92	0.00	0.10	0.04	-0.05	0.00	0.02
2001	0.12	-0.90	-0.14	-4.43	-4.28	0.93	-0.21	0.41	0.00	0.20	0.00	-0.27	-0.01	0.00
2002	0.10	-1.28	-0.07	-4.06	-4.27	1.55	0.40	0.02	0.00	0.14	-0.14	-0.50	-0.02	0.00
2003	-0.23	-0.91	0.07	-4.38	-4.78	1.17	0.23	-0.04	0.00	-0.23	-0.39	-0.49	-0.02	-0.01
2004	0.05	-0.90	0.07	-4.00	-4.60	1.10	-0.01	-0.03	-0.08	-0.28	-0.39	-0.87	-0.06	-0.08
2005	0.24	-1.24	0.05	-3.96	-4.20	0.81	0.41	-0.05	-0.07	-0.20	-0.47	-0.85	-0.09	-0.10
2006	0.43	-1.41	0.12	-4.37	-4.12	-0.41	-0.48	-0.05	-0.05	-0.06	-0.45	-0.84	-0.07	-0.09
2007	0.44	-1.10	0.02	-4.47	-4.16	-0.73	-0.26	-0.06	-0.09	-0.30	-0.46	-0.70	-0.07	-0.12
2008	0.23	-2.34	0.10	-4.65	-4.12	-1.89	-1.00	-0.15	-0.02	0.01	-0.79	-1.02	-0.07	-0.07
2009	0.21	-2.95	0.15	-4.91	-4.32	-3.04	-1.55	-0.26	-0.02	-0.12	-1.13	-1.17	-0.13	-0.07
2010	0.18	-3.11	0.17	-4.50	-3.40	-3.27	-1.11	-0.20	-0.05	-0.37	-0.61	-0.21	0.01	-0.02
2011	0.16	-3.79	0.15	-4.76	-4.50	-4.59	-1.74	0.12	0.27	-0.06	-0.68	-0.27	0.03	0.05
2012	0.24	-1.79	0.19	-3.84	-2.61	-3.64	-0.95	0.29	0.33	0.50	-0.09	-0.05	0.02	0.08
2013	0.24	-2.13	0.23	-3.63	-3.09	-4.19	-1.40	0.59	0.64	0.88	-0.20	-0.21	0.97	0.26
2014	0.20	-0.47	0.23	-3.41	-3.62	-4.75	-1.68	0.10	0.20	0.02	0.20	-0.43	-4.63	-0.05

8.2 Planned improvements

Specific improvements are specified in the QA/QC plan (ISPRA, 2017[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, and for POPs emissions the use of the results of a national research in the potential update of emission factors and methodologies. For the *agriculture* and *waste* sectors, improvements will be related to the availability of new information on emission factors, activity data as well as parameters necessary to carry out the estimates; specifically, a study on the best available technologies used in agriculture practices 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 2016 chapters (EMEP/EEA, 2016) has started to be considered, for PM2.5 and BC, 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 accuracy and reduce the uncertainty.

The comparison between local inventories and national inventory and the meetings and exchange of information with local environmental agencies will continue.

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

9 PROJECTIONS

9.1 The national framework

The emission scenarios have become increasingly important in the definition of international, European and national policies on atmospheric pollution.

At national level, the Legislative Decree n. 155 of 2010, art. 22 paragraph 4 provides that ISPRA has to develop the energy scenario and the scenario of national production activities (Caputo et al., 2015) and, based on these scenarios, ENEA has to calculate the emission projections using the methodology developed for these purposes at the European level.

In this framework, ENEA and ISPRA have jointly developed the new national baseline emission scenario using the GAINS-Italy model (Ciucci et al., 2016; D'Elia et al., 2009). GAINS-Italy is part of the MINNI model (National Integrated Model to support the International Negotiation on atmospheric pollution, Mircea et al., 2014; www.minni.org), an ENEA project, funded by MATTM (the Italian Ministry for the Environment, the Territory and the Sea), that reflects on a national scale the structure of the GAINS-Europe model (Amann et al., 2011), developed by the International Institute for Applied Systems Analysis (IIASA), but customizes the Italian case by adopting the division of the territory into regions and using a spatial resolution of 20 km.

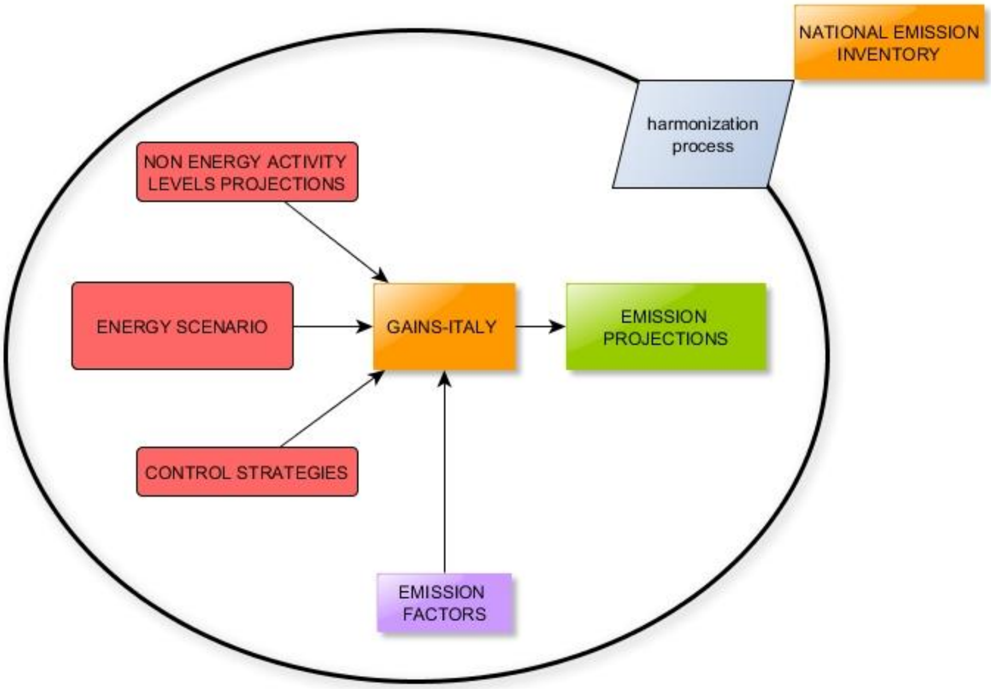

Figure 9.1 – *The scheme of data used and produced by the GAINS-Italy model*

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 (Figure 9.1). 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.

The GAINS-Italy model is accessible online at http://gains-it.bologna.enea.it/gains/IT/index.login (registration needed).

9.2 Input scenarios

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. The national energy scenario has been approved by all the competent administrations in November 2016 and is coherent with the latest available PRIMES 2016 scenario (Capros et al., 2016).

The national total fuel consumption can be summarized in figure 9.2.

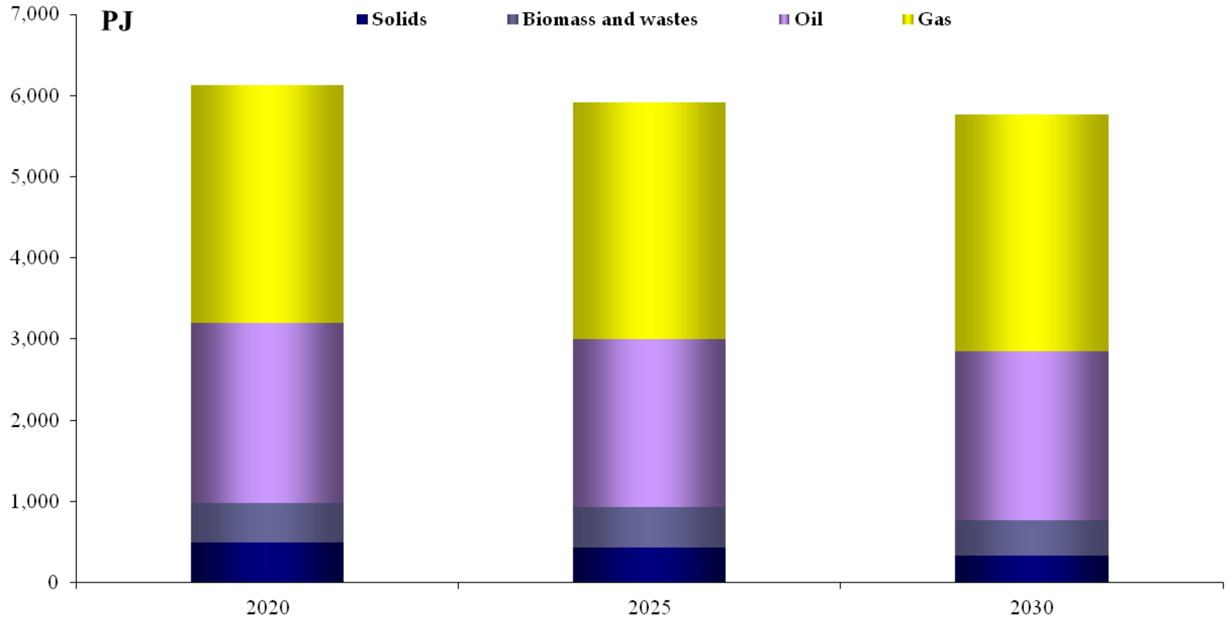

Figure 9.2 – *Projected total fuel consumptions (PJ).*

The scenario of non-energy activities

In order 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.

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. All the details about this methodology are provided in D'Elia and Peschi, 2013.

The evolution of the main livestock is summarized in fig. 9.3.

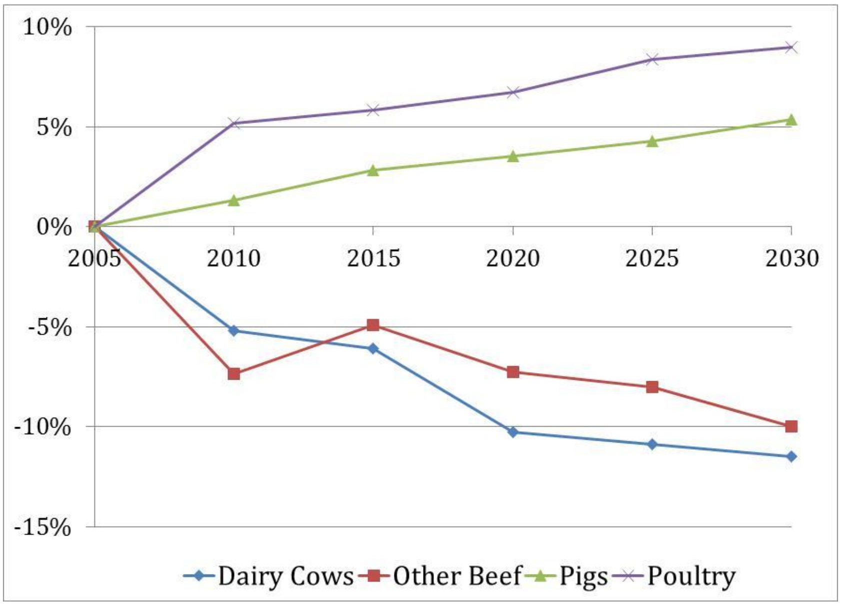

Figure 9.3 – *National livestock trend for the baseline scenario.*

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 baseline scenario it is assumed that all the European and national regulations 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.

9.3 The harmonization process

The GAINS-Italy model attempts to reproduce the national emission inventory officially submitted as closely as possible. Anyway, being the model a detailed but simplified representation of the reality and having adopted a different classification code respect to the inventory and a different methodology, harmonization process is needed so to validate and make more reliable an emission scenario.

For this reason an in-depth comparison and harmonization have been carried out considering the year 2010, whose results are summarized in table 9.1. For the year 2015 the harmonization process is still ongoing.

Table 9.1 – *Comparison of total emissions in the last submission of the national inventory report and in GAINS-Italy estimates for the year 2010.*

	2010 Emissions (kt)		
Pollutant	**Inventory**	**Gains-Italy**	**Δ%**
SO_2	217	208	-4.10%
NOx	948	981	3.40%
PM2.5	190	196	3.20%
NMVOC	1001	1005	0.40%
NH3	389	389	-0.10%

Discrepancies in reproducing the national total emission inventory have been considered acceptable if differences remain within a few percentage points, i.e. in the interval between ±5%.

In the following figure major details on sectoral emissions are reported for the year 2010.

A good alignment has been reached in SO_2 sectoral emissions. Small differences between modelled and inventory emissions remain in energy industries and manufacturing industries, essentially due to different allocation of activities in the two sectors.

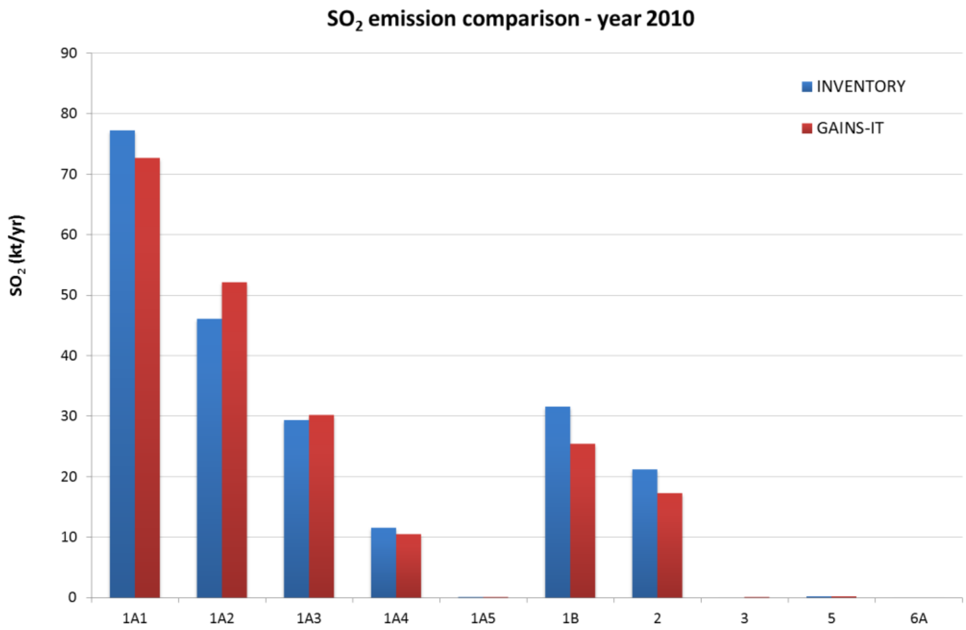

Figure 9.4 – *SO_2 national emission harmonization between the last emission inventory and GAINS-IT detailed by sectors for the year 2010.*

The harmonization of NO_X emissions shows a good agreement not only in total emissions but also by sectors and road transport represents the main emitting sector.

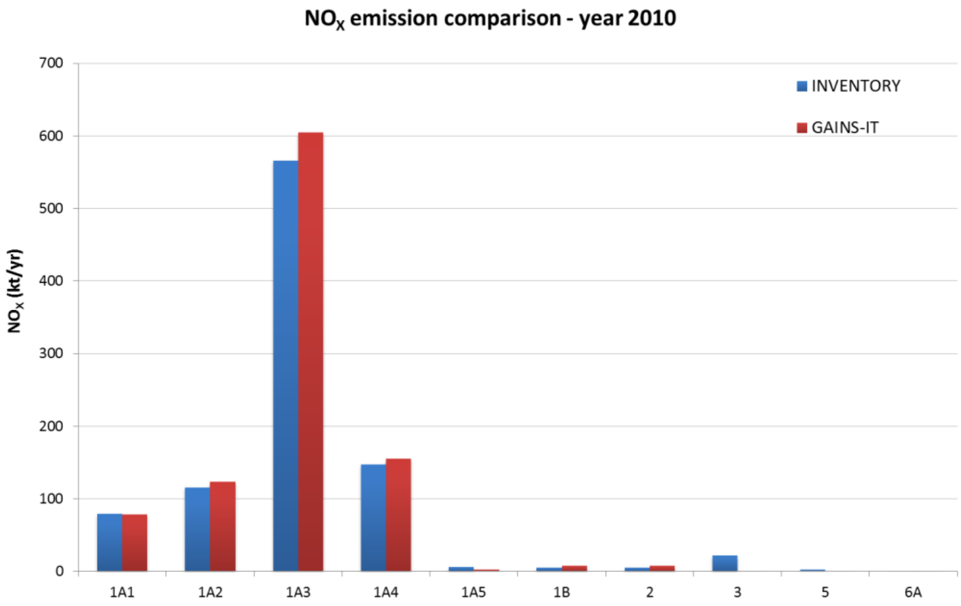

Figure 9.5 – *NOx national emission harmonization between the last emission inventory and GAINS-IT detailed by sectors for the year 2010.*

PM2.5 emissions from GAINS-Italy are very close to those reported in the national emission inventory where the civil sector (1A4) represents more than 60% of the total national PM2.5 emissions. The emissions from barbecue and fireworks estimated by the model have been reported in sector 6A.

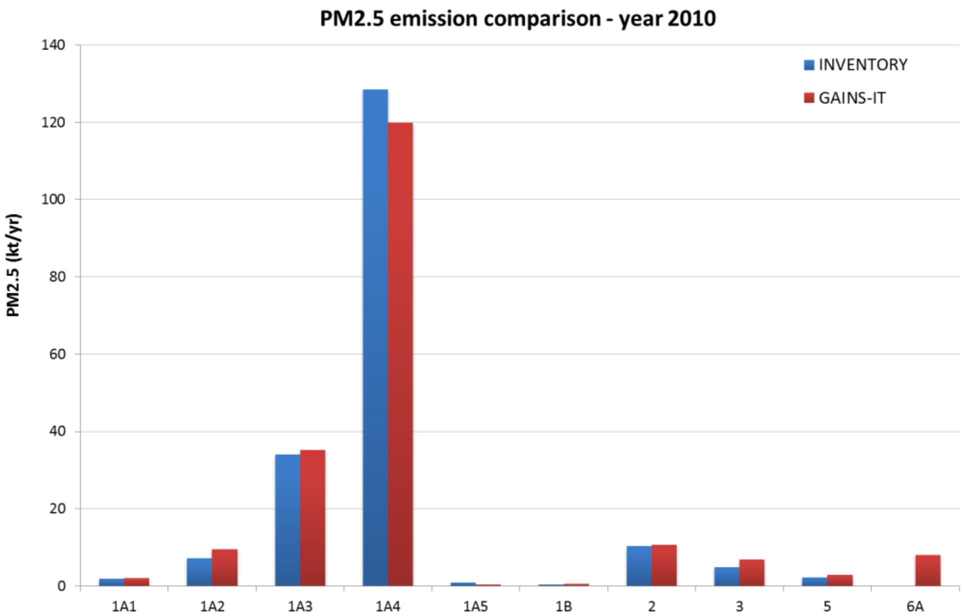

Figure 9.6 – *PM2.5 national emission harmonization between the last emission inventory and GAINS-IT detailed by sectors for the year 2010.*

Also for NMVOC it is possible to observe a good sectoral agreement between emission modelled and estimated in the inventory. The use of solvent (in domestic and industrial sector) remains the main emitting sector.

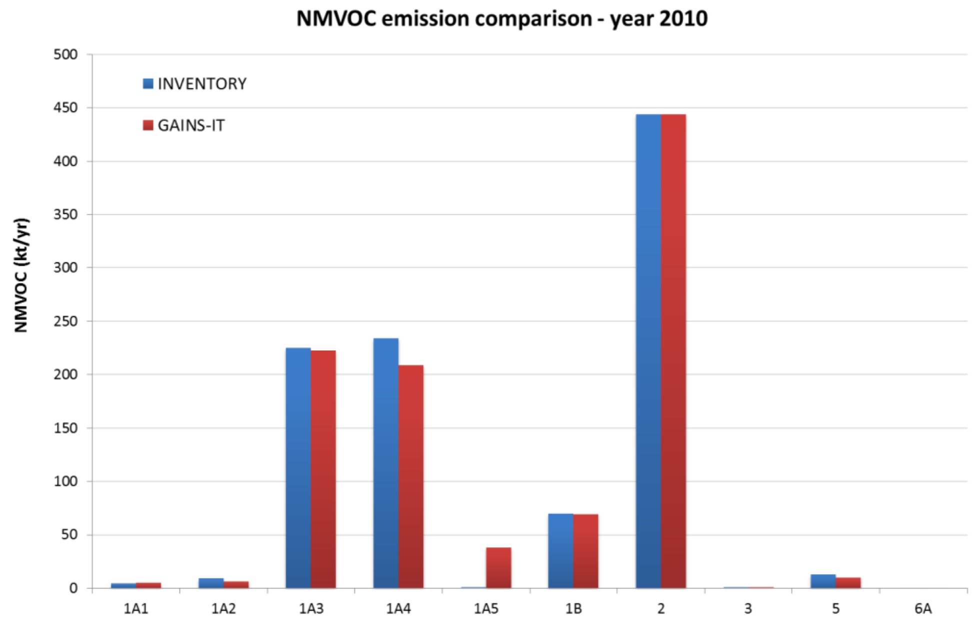

Figure 9.7 – *NMVOC national emission harmonization between the last emission inventory and GAINS-IT detailed by sectors for the year 2010.*

A good agreement also at a sectoral level is observed for NH_3 emissions where the agriculture sector represents the main source with more than 95% of total NH_3 emissions.

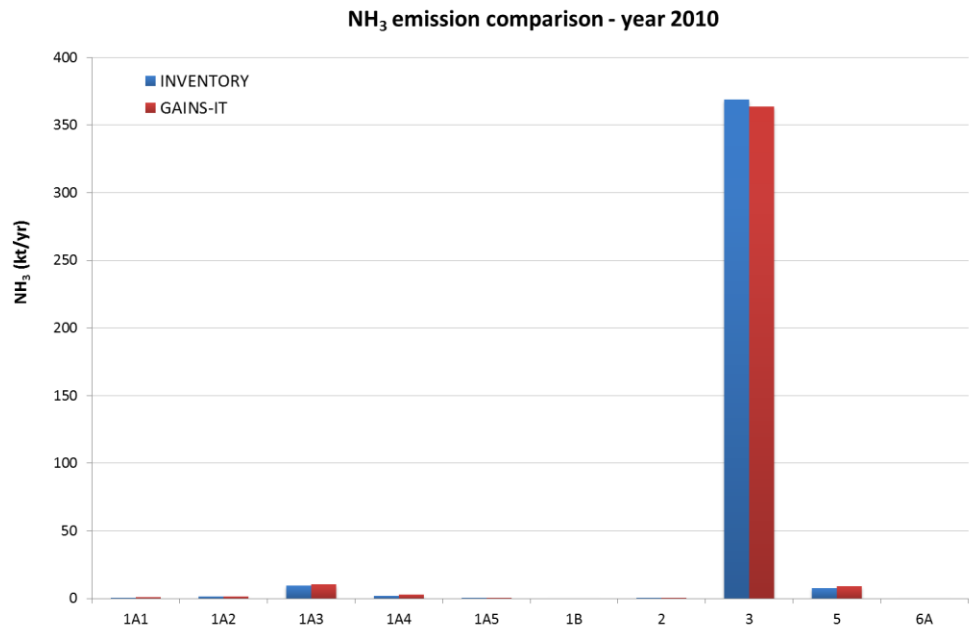

Figure 9.8 – *NH_3 national emission harmonization between the last emission inventory and GAINS-IT detailed by sectors for the year 2010.*

9.4 The emission scenario

The result of the input scenarios and of the harmonization process is an emission scenario.

In Figures 9.9-9.13 the projections for the years 2020, 2025 and 2030 are presented.

A huge decrease in SO_2 emissions from the energy and the maritime sector is projected for the year 2020 and 2030 while the industrial sector represents the main emitter (fig. 9.9).

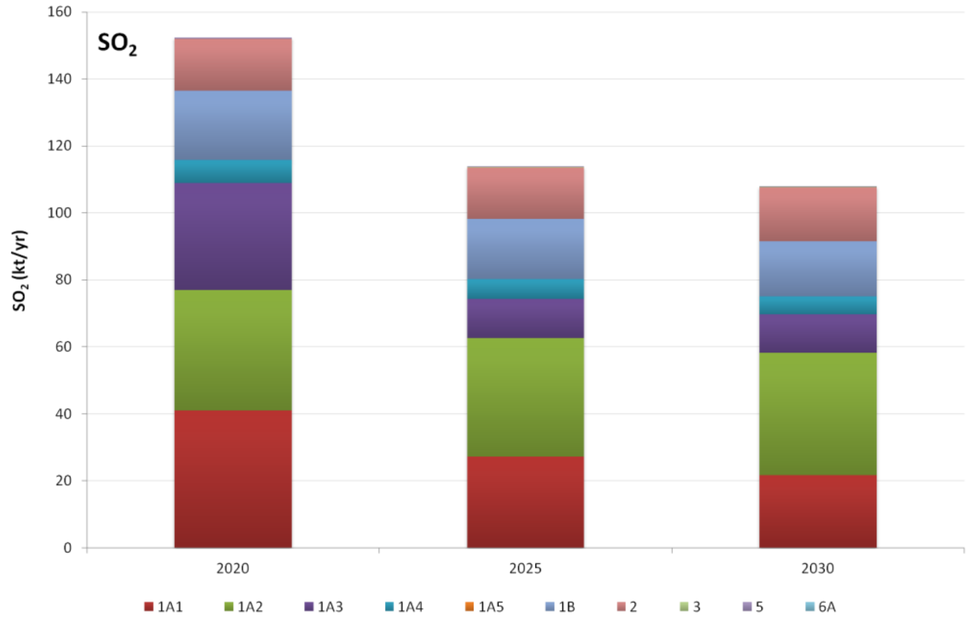

Figure 9.9 – *Projected emissions of SO_2 for the year 2020, 2025 and 2030.*

The road transport sector still represents the principle NO_X source (fig. 9.10) even though a huge decrease is estimated due to the diffusion of Euro 6 vehicles.

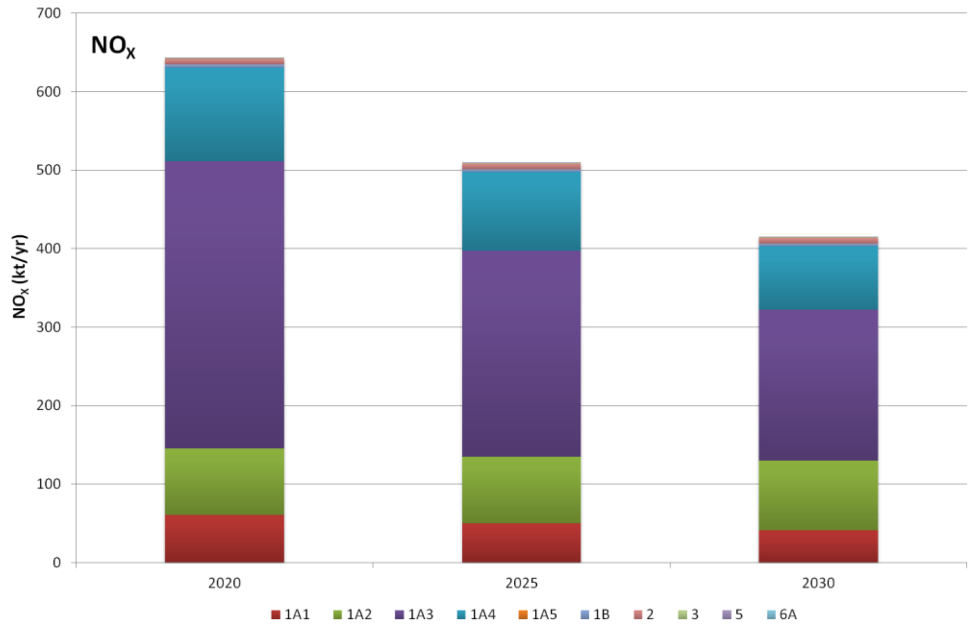

Figure 9.10 – *Projected emissions of NO_X for the year 2020, 2025 and 2030.*

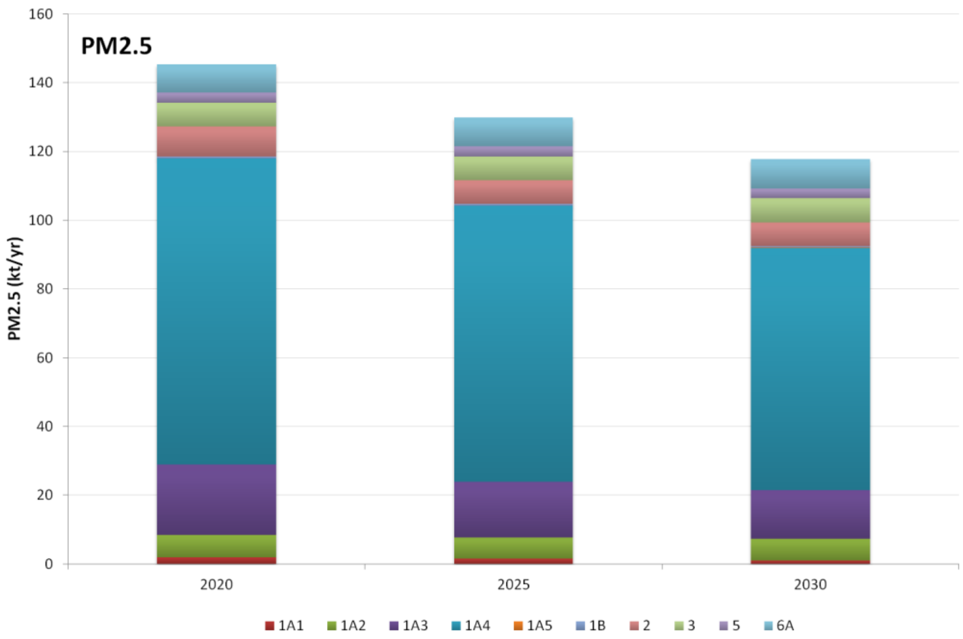

Figure 9.11 – *Projected emissions of PM2.5 for the year 2020, 2025 and 2030.*

The civil sector continues to represent the main emitting sector for PM2.5 emissions whose contribution remains around 60% both for 2020 and 2030 (fig. 9.11). The main emitting sector for NMVOC is still represented by domestic and industrial solvent use (fig. 9.12) whose emissions are not projected to decrease. NH_3 scenario does not present a significant variation in emissions where the contribution of the agricultural sector to total NH_3 emissions is around 95% (fig. 9.13). Cattle continue to be the most emitting sector followed by the use of urea and pigs.

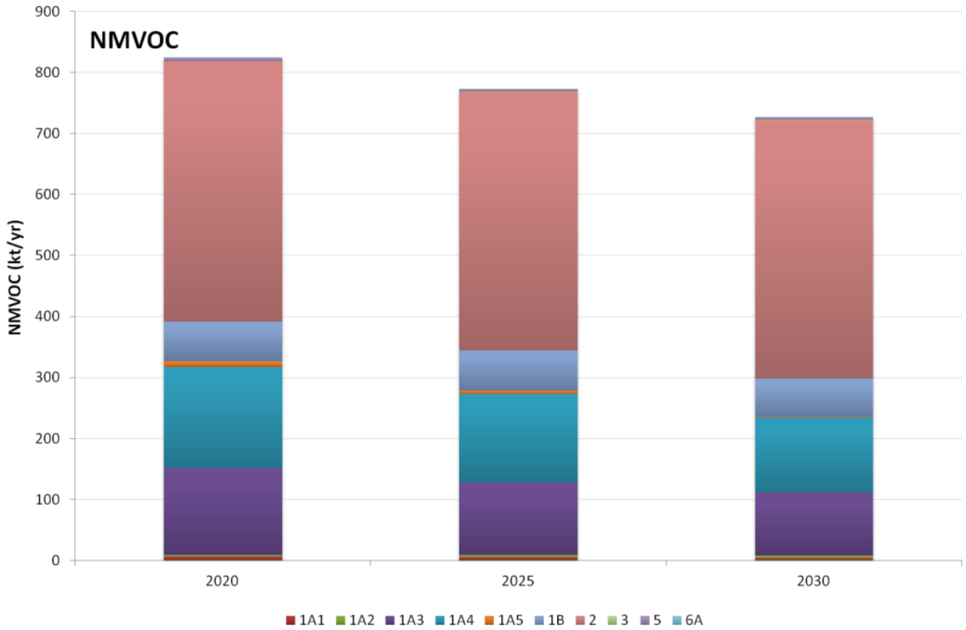

Figure 9.12 – *Projected emissions of NMVOC for the year 2020, 2025 and 2030.*

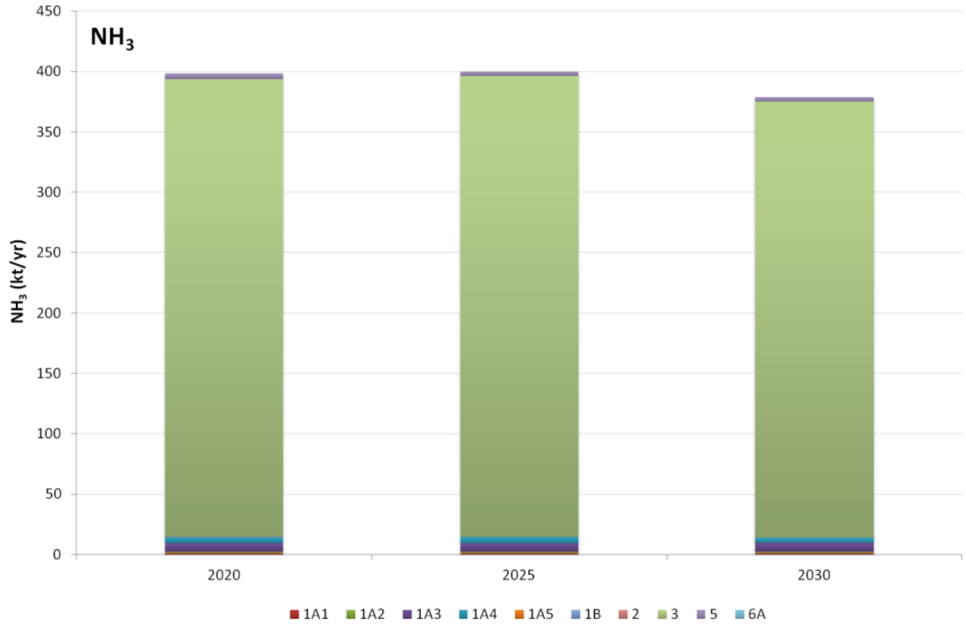

Figure 9.13 – *Projected emissions of NH_3 for the year 2020, 2025 and 2030.*

In table 9.2 the national emission reductions in the year 2020 and 2030 respect to the base year 2005 and the comparison with the new National Emission Ceilings Directive (NECD) targets (EC, 2016) are reported.

Table 9.2 – *National emission reductions in the year 2020 and 2030 respect to the base year 2005 and comparison with the new National Emission Ceilings Directive (NECD) targets.*

	Emission reductions from 2005			
	2020		2030	
	NECD target	National emission scenario	NECD target	National emission scenario
SO_2	-35%	-61%	-71%	-73%
NO_x	-40%	-48%	-65%	-66%
PM2.5	-10%	-17%	-40%	-33%
NMVOC	-35%	-35%	-46%	-43%
NH_3	-5%	-7%	-16%	-11%

According to the present emission projections, all the targets should be met in 2020 even though attention should be paid to the NMVOC emission reduction, while for the 2030 targets additional measures should be adopted to respect the PM2.5, NMVOC and NH_3 targets.

10 REFERENCES

10.1 Introduction

EMEP/CORINAIR, 2007. Atmospheric Emission Inventory Guidebook. Technical report No 16/2007.

EMEP/EEA, 2009. Air Pollutant Emission Inventory Guidebook. EEA. Technical report No 9/2009.

EMEP/EEA, 2013. Air Pollutant Emission Inventory Guidebook. EEA. Technical report No 12/2013.

EMEP/EEA, 2016. Air Pollutant Emission Inventory Guidebook. EEA. Technical report No 21/2016.

IPCC, 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories*. Three volumes: Reference Manual, Reporting Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Centre, Meteorological Office, Bracknell, UK.

IPCC, 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit, Hayama, Kanagawa, Japan.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

ISPRA, 2009. La disaggregazione a livello provinciale dell'inventario nazionale delle emissioni. Anni 1990-1995-2000-2005. ISPRA, 92/2009. URL: http://www.apat.gov.it/site/it-IT/APAT/Pubblicazioni/Rapporti/Documento/rapporti_92_2009.html.

ISPRA, 2014. Quality Assurance/Quality Control plan for the Italian Emission Inventory. Procedures Manual. Report 112/2014. http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni.

ISPRA, 2016. National Greenhouse Gas Inventory System in Italy. March 2016, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni.

ISPRA, 2017[a]. Italian Greenhouse Gas Inventory 1990-2015. National Inventory Report 2017. March 2017, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni.

ISPRA, 2017[b]. Quality Assurance/Quality Control plan for the Italian Emission Inventory. Year 2017. March 2017, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni.

Romano D., Bernetti A., De Lauretis R., 2004. Different methodologies to quantify uncertainties of air emissions. Environment International vol 30 pp 1099-1107.

UNECE, 2008. Guidelines for Reporting Emission Data under the Convention on Long-range Transboundary Air Pollution, Emission Reporting Guidelines. ECE/EB.AIR/2008/4 23 September 2008.

UNECE, 2010. Report for the Stage 3 in-depth review of emission inventories submitted under the UNECE LRTAP Convention and EU National Emissions Ceilings Directive for Italy. CEIP/S3.RR/2010/ITALY (25/11/2010).

UNECE, 2013. Report for the Stage 3 in-depth review of emission inventories submitted under the UNECE LRTAP Convention and EU National Emissions Ceilings Directive for Italy. CEIP/S3.RR/2013/ITALY (20/08/2013)

UNECE, 2014. Guidelines for Reporting Emissions and Projections Data under the Convention on Long Range Transboundary Air Pollution, ECE/EB.AIR/125 13 March 2014.

10.2 Analysis of key trends by pollutant

EC, 1975. Council Directive 75/716/EEC of 24 November 1975 on the approximation of the laws of the Member States relating to the sulphur content of certain liquid fuels.

EC, 1988. Council Directive 88/609/EEC of 24 November 1988 on the limitation of emissions of certain pollutants into the air from large combustion plants.

EC, 1991. Council Directive 91/441/EEC of 26 June 1991 amending Directive 70/220/EEC on the approximation of the laws of the Member States relating to measures to be taken against air pollution by emissions from motor vehicles.

EC, 1994. Directive 94/12/EC of the European Parliament and the Council of 23 March 1994 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Directive 70/220/EEC.

EC, 1996. Council directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control. Official Journal L 257 , 10/10/1996 P. 0026 – 0040.

EC, 1997 [a]. Directive 97/68/EC of the European Parliament and of the Council of 16 December 1997 on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery.

EC, 1997 [b]. Directive 97/24/EC of the European Parliament and of the Council of 17 June 1997 on certain components and characteristics of two or three-wheel motor vehicles.

EC, 1998. Directive 98/69/EC of the European Parliament and of the Council of 13 October 1998 relating to measures to be taken against air pollution by emissions from motor vehicles and amending Council Directive 70/220/EEC.

EC, 1999. Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations.

EC, 2001. National Emission Ceilings Directive: Directive 2001/81/EC.

EC, 2004. Council Directive 2004/26/EC of 21 April 2004 amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery.

Decree of President of the Republic 24 May 1988, n. 203. Attuazione delle direttive CEE numeri 80/779, 82/884, 84/360 e 85/203 concernenti norme in materia di qualità dell'aria, relativamente a specifici agenti inquinanti, e di inquinamento prodotto dagli impianti industriali, ai sensi dell'art. 15 della L. 16 aprile 1987, n. 183 (2) (2/a). Gazzetta Ufficiale del 16 giugno 1988, n. 140, S.O.

ISTAT, 2014. I consumi energetici delle famiglie, anno 2013. http://www.istat.it/it/archivio/142173

Ministerial Decree 8 May 1989. Limitazione delle emissioni in atmosfera di taluni inquinanti originati dai grandi impianti di combustione. Gazzetta Ufficiale Italiana n. 124 del 30/05/1989.

Ministerial Decree 12 July 1990. Linee Guida per il contenimento delle emissioni inquinanti degli impianti industriali e la fissazione dei valori minimi di emissione. G.U. 30 luglio 1990, n. 176.

Ministerial Decree 16 May 1996, n. 392. Regolamento recante norme tecniche relative alla eliminazione degli olii usati. G. U. n. 173 del 25/07/1996.

Ministerial Decree 21 January 2000, n. 107. Regolamento recante norme tecniche per l'adeguamento degli impianti di deposito di benzina ai fini del controllo delle emissioni dei vapori. G. U. 02/05/2000 n. 100.

MSE, several years [a]. Bilancio Energetico Nazionale (BEN). Ministero delle Attività Produttive, Direzione Generale delle Fonti di Energia ed industrie di base. http://dgerm.sviluppoeconomico.gov.it/dgerm/ben.asp .

10.3 Energy (NRF sector 1)

ACI, several years. Annuario statistico. Automobile Club d'Italia, Roma. http://www.aci.it/index.php?id=54.

AISCAT, several years. Aiscat in cifre. Data and reports available on website at: http://www.aiscat.it/pubb_cifre.htm?ck=1&sub=3&idl=4&nome=pubblicazioni&nome_sub=aiscat%20in%20cifre.

ANCMA, several years. Data available on website at: http://www.ancma.it/statistiche-/-statistics.

ANPA, 2001. Redazione di inventari nazionali delle emissioni in atmosfera nei settori del trasporto aereo e marittimo e delle emissioni biogeniche. Rapporto finale. Gennaio 2001

ARPA, 2007 – Stima dei consumi di legna da ardere ed uso domestico in Italia. Ricerca commissionata da APAT e ARPA Lombardia, Rapporto finale, marzo 2007.

ASSOTERMICA, several years. Studio Statistico, http://www.anima.it/contenuti/10670/studi-di-mercato.

CESI, 2005. Caratterizzazione delle emissioni di caldaie residenziali, CESI, 2005.

CONFETRA, several years. Il trasporto merci su strada in Italia. Data and reports available on website at: http://www.confetra.it/it/centrostudi/statistiche.htm.

Decree of President of the Republic 24 May 1988, n. 203. Attuazione delle direttive CEE numeri 80/779, 82/884, 84/360 e 85/203 concernenti norme in materia di qualità dell'aria, relativamente a specifici agenti inquinanti, e di inquinamento prodotto dagli impianti industriali, ai sensi dell'art. 15 della L. 16 aprile 1987, n. 183 (2) (2/a). Gazzetta Ufficiale del 16 giugno 1988, n. 140, S.O.

EC, 2004. Council Directive 2004/26/EC of 21 April 2004 amending Directive 97/68/EC on the approximation of the laws of the Member States relating to measures against the emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery.

EEA, several years, Monitoring CO_2 emissions from passenger cars and vans, EEA technical reports.

EMEP/CORINAIR, 2007. Atmospheric Emission Inventory Guidebook. Technical report No 16/2007.

EMEP/EEA, 2013. Air Pollutant Emission Inventory Guidebook. EEA. Technical report No 12/2013.

EMEP/EEA, 2016. Air Pollutant Emission Inventory Guidebook. EEA. Technical report No 21/2016.

EMISIA SA, 2016. COPERT 4 v 11.4, Computer programme to calculate emissions from road transport, September 2016. http://www.emisia.com/copert/.

ENAC/MIT, several years. Annuario Statistico. Ente Nazionale per l'Aviazione Civile, Ministero delle Infrastrutture e dei Trasporti.

ENEA, several years. Rapporto Energia Ambiente. Ente per le Nuove tecnologie, l'Energia e l'Ambiente, Roma.

ENEA-federAmbiente, 2012. Rapporto sul recupero energetico da rifiuti urbani in Italia. 3° ed.

EUROCONTROL, 2016. EUROCONTROL Fuel and Emissions Inventory. Personal Communication to EU Member States. November 2016.

Fuel Experimental Station (Innovhub), several years, Report on the physico-chemical characterization of fossil fuels used in Italy.

Gerardi V., Perrella G., 2001 - I consumi energetici di biomasse nel settore residenziale in Italia nel 1999. ENEA, Ente Nazionale per l'Energia e l'Ambiente, 2001, ENEA RT/ERG/2001/07.

Giordano R., 2007. Trasporto merci: criticità attuali e potenziali sviluppi nel contesto europeo. National road transporters central committee.

IPCC, 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories*. Three volumes: Reference Manual, Reporting Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Centre, Meteorological Office, Bracknell, UK.

IPCC, 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit, Hayama, Kanagawa, Japan.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

ISPRA, 2009. La disaggregazione a livello provinciale dell'inventario nazionale delle emissioni. Anni 1990-

1995-2000-2005. ISPRA, 92/2009. URL: http://www.apat.gov.it/site/it-IT/APAT/Pubblicazioni/Rapporti/Documento/rapporti_92_2009.html.

ISPRA, 2016. Annuario dei dati ambientali 2016. Report 69/2016. http://www.isprambiente.gov.it/it/pubblicazioni/stato-dellambiente/annuario-dei-dati-ambientali-edizione-2016 .

ISPRA, 2017[a]. Italian Greenhouse Gas Inventory 1990-2015. National Inventory Report 2017. March 2017, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni.

ISPRA, 2017[b]. Quality Assurance/Quality Control plan for the Italian Emission Inventory. Year 2017. March 2017, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni.

ISPRA, several years. Fuel Quality Monitoring Annual Report.

ISTAT, 2009. Personal communication.

ISTAT, 2014. I consumi energetici delle famiglie, 2013. Nota metodologica. Istituto Nazionale di Statistica www.istat.it .

ISTAT, several years [a]. Annuario Statistico Italiano. Istituto Nazionale di Statistica

ISTAT, several years [b]. Trasporto merci su strada. Istituto Nazionale di Statistica. http://www3.istat.it/dati/dataset/20110729_00/.

Katsis P., Mellios G., Ntziachristos L., 2012. Description of new elements in COPERT 4 v 10.0, December 2012.

Kouridis C., Gkatzoflias D., Kioutsioukis I., Ntziachristos L., Pastorello C., Dilara P., 2010. Uncertainty Estimates and Guidance for Road Transport Emission Calculations, European Commission, Joint Research Centre, Institute for Environment and Sustainability, 2010, http://www.emisia.com/docs/COPERT%20uncertainty.pdf.

Ministerial Decree 12 July 1990. Linee Guida per il contenimento delle emissioni inquinanti degli impianti industriali e la fissazione dei valori minimi di emissione. G.U. 30 luglio 1990, n. 176.

MIT, several years. Conto Nazionale delle Infrastrutture e dei Trasporti (CNT). Ministero delle Infrastrutture e dei Trasporti. http://www.mit.gov.it/mit/site.php?o=vc&lm=2&id_cat=148.

MSE, several years [a]. Bilancio Energetico Nazionale (BEN). Ministero delle Attività Produttive, Direzione Generale delle Fonti di Energia ed industrie di base. http://dgerm.sviluppoeconomico.gov.it/dgerm/ben.asp.

MSE, several years [b]. Bollettino Petrolifero Trimestrale (BPT). Ministero dello sviluppo economico. http://dgerm.sviluppoeconomico.gov.it/dgerm/bollettino.asp .

Romano D., Gaudioso D., De Lauretis R., 1999. Aircraft Emissions: a comparison of methodologies based on different data availability. Environmental Monitoring and Assessment. Vol. 56 pp. 51-74.

SCENARI/ISPRA, 2013. Indagine sull’uso e la disponibilità delle biomasse in Italia. 2013.

SSC, 2012. Final report on emissions from biomass combustion for heating. Stazione Sperimentale dei Combustibili. Prot. ENEA/2009/34883/APU-UGA March 2012.

TECHNE, 2009. Stima delle emissioni in atmosfera nel settore del trasporto aereo e marittimo. Final report. TECHNE Consulting, March 2009.

TERNA, several years. Dati statistici sugli impianti e la produzione di energia elettrica in Italia, Gestore Rete Trasmissione Nazionale. www.terna.it.

Trozzi C., Vaccaro R., De Lauretis R., Romano D., 2002 [a]. Air pollutant emissions estimate from global air traffic in airport and in cruise: methodology and case study. Presented at Transport and Air Pollution 2002.

Trozzi C., Vaccaro R., De Lauretis R., 2002 [b]. Air pollutant emissions estimate from global ship traffic in port and in cruise: methodology and case study. Presented at Transport and Air Pollution 2002.

UCINA, several years. La nautica in cifre. Analisi annuale del mercato. Unione Nazionale Cantieri Industrie

Nautiche ed Affini.

UP, several years. Previsioni di domanda energetica e petrolifera in Italia. Unione Petrolifera.

10.4 IPPU - Industrial processes (NRF sector 2)

APAT, 2003. Il ciclo industriale dell'acciaio da forno elettrico. Agenzia per la Protezione dell'Ambiente e per i servizi tecnici, Rapporti 38/2003.

AITEC, 2015. Relazione annuale 2015. Associazione italiana tecnico economica del cemento. www.aitecweb.com .

CORINAIR, 1994. Default emission factors handbook. EUR 12586/2, Belgium.

EMEP/CORINAIR, 2006. Atmospheric Emission Inventory Guidebook. Technical report No 11/2006.

EMEP/CORINAIR, 2007. Atmospheric Emission Inventory Guidebook. Technical report No 16/2007.

EMEP/EEA, 2013. Air Pollutant Emission Inventory Guidebook. Technical report n. 12/2013.

ENEA-AIB-MATT, 2002. "Valutazione delle emissioni di inquinanti organici persistenti da parte dell'industria metallurgica secondaria".

EUROCHLOR, 1998. Mercury process for making chlorine.

EUROCHLOR, 2001. Reduction of Mercury Emissions from the West European Chlor-Alkali Industry, June 2001 available on the web http://www.chem.unep.ch/mercury/2001-ngo-sub/eurochlor/sub1ngoatt8.pdf.

FEDERACCIAI, several years. La siderurgia in cifre. Federazione Imprese Siderurgiche Italiane.

ILVA, 1997. Personal communication.

IPCC, 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories*. Three volumes: Reference Manual, Reporting Manual, Reporting Guidelines and Workbook.

IPCC, 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit, Hayama, Kanagawa, Japan.

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

IPPC, 2001. Best Available Techniques Reference Document on the Production of Iron and Steel. Integrated Pollution Prevention and Control. European Commission. December 2001.

ISPRA, 2009. La disaggregazione a livello provinciale dell'inventario nazionale delle emissioni. Anni 1990-1995-2000-2005. ISPRA, 92/2009. http://www.isprambiente.gov.it/it/pubblicazioni/rapporti/la-disaggregazione-a-livello-provinciale .

ISTAT, several years. Annuario Statistico Italiano. Istituto Nazionale di Statistica.

Legambiente, 2007. Lo stato dell'arte sulle riconversioni degli impianti cloro soda in Italia, Ottobre 2007 available on the web:
http://risorse.legambiente.it/docs/Lo_stato_dell_arte_sulle_riconversioni_degli_impianti_cloro-soda_in_Italia_ott_2007.0000001526.pdf

MATTM, 2011. Autorizzazione integrata ambientale per l'esercizio dello stabilimento siderurgico della società ILVA s.p.a. ubicato nel comune di Taranto. IPPC permit.

MSE, several years.Statistiche produzione cementi. http://www.sviluppoeconomico.gov.it/index.php/it/per-i-media/statistiche/2009708-statistiche-produzione-cementi.

TNO, 1992. Emission factors manual PARCOM – ATMOS. Emission factors for air pollutants 1992.

10.5 IPPU - Solvent and other product use (NRF sector 2)

ACI, several years. Annuario statistico. Automobile Club d'Italia, Roma. http://www.aci.it/index.php?id=54.

AIA, several years [a]. Personal Communication. Associazione Italiana Aerosol.

AIA, several years [b]. Relazioni annuali sulla produzione italiana aerosol. Associazione Italiana Aerosol.

Assocasa, several years. Personal Communication.

AVISA, several years. Personal Communication.

CEPE, 1999. European guidelines for car repairing.

EC, 1999. Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations.

EC, 2002. Screening study to identify reduction in VOC emissions due to the restrictions in the VOC content of products. Final Report of the European Commission, February 2002.

EC, 2004. Directive 2004/42/ce of the european parliament and of the council of 21 April 2004 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 and amending Directive 1999/13/EC.

EMEP/CORINAIR, 2007. Atmospheric Emission Inventory Guidebook. Technical report No 16/2007.

EMEP/EEA, 2016. Air Pollutant Emission Inventory Guidebook. EEA. Technical report No 21/2016.

ENEA/USLRMA, 1995. Lavanderie a secco.

FAO, several years. Food balance. http://faostat.fao.org .

FIAT, several years. Rendiconto Ambientale. Gruppo Fiat.

GIADA, 2006. Progetto Giada and Personal Communication. ARPA Veneto – Provincia di Vicenza.

ISPRA, 2009. La disaggregazione a livello provinciale dell'inventario nazionale delle emissioni. Anni 1990-1995-2000-2005. ISPRA, 92/2009. URL: http://www.apat.gov.it/site/it-IT/APAT/Pubblicazioni/Rapporti/Documento/rapporti_92_2009.html

ISTAT, several years [a]. Annuario Statistico Italiano.

ISTAT, several years [b]. Bollettino mensile di statistica.

ISTAT, several years [c]. Statistica annuale della produzione industriale. http://www.istat.it/it/archivio/73150

MICA, 1999. L'industria Italiana delle vernici. Ministero dell'Industria del Commercio e dell'Artigianato. Dicembre 1999.

Offredi P., several years. Professione Verniciatore del Legno. Personal communication.

Regione Campania, 2005. Inventario regionale delle emissioni di inquinanti dell'aria della Regione Campania, marzo 2005.

Regione Toscana, 2001. Inventario regionale delle sorgenti di emissione in aria ambiente, febbraio 2001.

Techne, 1998. Personal communication.

Techne, 2004. Progetto MeditAiraneo. Rassegna dei fattori di emissione nazionali ed internazionali relativamente al settore solventi. Rapporto Finale, novembre 2004.

Techne, 2008. Fattori di emissione per l'utilizzo di solventi. Rapporto Finale, marzo 2008.

UNIPRO, several years. Rapporto Annuale - Consumi cosmetici in Italia.

Vetrella G., 1994. Strategie ottimali per la riduzione delle emissioni di composti organici volatili. Thesis in Statistics.

10.6 Agriculture (NRF sector 3)

APAT, 2005. Methodologies used in Italy for the estimation of air emission in the agriculture sector. Technical report 64/2005. Rome - Italy. URL: http://www.isprambiente.gov.it/it/pubblicazioni/rapporti

Bassanino M., Sacco D., Zavattaro L., Grignania C., 2011. Nutrient balance as a sustainability indicator of different agro-environments in Italy. Ecol Indic 11(2): 715-723

Bechini L., Castoldi N., 2009. On-farm monitoring of economic and environmental performances of cropping systems: Results of a 2-year study at the field scale in northern Italy. Ecol Indic 9: 1096–1113

Berdowski J.J.M., Baas J, Bloos JP.J., Visschedijk A.J.H., Zandveld P.Y.J., 1997. The European Atmospheric Emission Inventory for Heavy Metals and Persistent Organic Pollutants. Umweltforschungsplan des Bundesministers fur Umwelt, Naturschutz und Reaktorsicherheit Luftreinhaltung. Forschungbericht 104 02 672/03. TNO, Apeldoorn, The Netherlands

Cóndor R.D., De Lauretis R., 2007. Agriculture emission inventory in Italy: synergies among conventions and directives. In: Ammonia emissions in Agriculture. Ed. G.J. Monteny, E. Hartung. Wageningen Academic Publishers. 404 p. The Netherlands

Cóndor R.D., Di Cristofaro E., De Lauretis R., 2008. Agricoltura: inventario nazionale delle emissioni e disaggregazione provinciale. Istituto superiore per la protezione e la ricerca ambientale, ISPRA Rapporto tecnico 85/2008. Roma, Italia. URL: http://www.isprambiente.gov.it/it/pubblicazioni/rapporti

Cóndor R.D., 2011. Agricoltura: emissioni nazionali in atmosfera dal 1990 al 2009. Istituto superiore per la protezione e la ricerca ambientale (ISPRA). Rapporto ISPRA 140/2011. Roma, Italia. URL: http://www.isprambiente.gov.it/it/pubblicazioni/rapporti/agricoltura-emissioni-nazionali-in-atmosfera-dal

Cóndor R.D., Valli L., 2011. Emissioni nazionali di ammoniaca e scenari emissivi derivanti dalla fase di spandimento agronomico e all'uso dei fertilizzanti azotati in Italia. e-book edited by the Centro Ricerche Produzioni Animali (CRPA). URL: http://www.crpa.it/media/documents/crpa_www/Pubblicazi/E-book/Ammoniaca2011/EmissioniAmmoniaca.pdf

CRPA, 2006[a]. Progetto MeditAIRaneo: settore Agricoltura. Relazione finale. Technical report on the framework of the MeditAIRaneo project for the Agriculture sector, Reggio Emilia - Italy

CRPA, 2006[b]. Predisposizione di scenari di emissione finalizzati alla progettazione di interventi per la riduzione delle emissioni nazionali di ammoniaca ed alla valutazione di misure e di progetti per la tutela della qualità dell'aria a livello regionale. Final report. Reggio Emilia - Italy

CRPA, 2010[a]. Personal communication - experts Laura Valli and Maria Teresa Pacchioli from the Research Centre on Animal Production (expert consultation on N excretion and national production systems). Reggio Emilia, Italy

CRPA, 2010[b]. Valutazione dell'entità delle emissioni ammoniacali derivanti dall'applicazione al suolo dei fertilizzanti, delle loro possibilità di riduzione e individuazione degli elementi per un monitoraggio statistico delle tecniche di applicazione utilizzate. Report. Reggio Emilia – Italy

EC, 1986. Council Directive 86/278/EC. Council Directive 86/278/EC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. Official Journal of the European Communities 4 July 1986

EEA, 2016. Analysis of key trends and drivers in greenhouse gas emissions in the EU between 1990 and 2014. Technical paper, June 2016. http://www.eea.europa.eu/publications/analysis-of-key-trends-ghg/

EMEP/CORINAIR, 2006. Atmospheric Emission Inventory Guidebook. Technical report No 11/2006

EMEP/CORINAIR, 2007. Atmospheric Emission Inventory Guidebook. Technical report No 16/2007

EMEP/EEA, 2013. Air Pollutant Emission Inventory Guidebook. Technical report n. 12/2013

EMEP/EEA, 2016. Air Pollutant Emission Inventory Guidebook. Technical report n. 21/2016

ENEA, 2006. Valutazione della possibilità di sostituzione dell'urea con altri fertilizzanti azotati. Final report. Rome, Italy

EPA, 1995. AP-42 Compilation of Air Emission Factors, 5th edition January 1995. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors

Giardini L., 1983. Agronomia Generale, Patron, Bologna

GU, Gazzetta Ufficiale della Repubblica Italiana, 2006. Criteri e norme tecniche generali per la disciplina regionale dell'utilizzazione agronomica degli effluenti di allevamento e di acque reflue di cui all'articolo 38 del decreto legislativo 11 maggio 1999 N. 152. G.U. n. 109 del 12/05/06 - Suppl. Ordinario n.120. Ministero delle Politiche Agricole e Forestali. Italy. http://www.gazzettaufficiale.it/

IPCC, 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories*. Three volumes: Reference Manual, Reporting Manual, Reporting Guidelines and Workbook

IPCC, 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories

IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit, Hayama, Kanagawa, Japan

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan

ISPRA, 2008. Database della disaggregazione a livello provinciale dell'Inventario nazionale delle emissioni:1990-1995-2000-2005. Istituto Superiore per la Protezione e la Ricerca Ambientale, ISPRA. URL: http://www.sinanet.isprambiente.it/it/inventaria/disaggregazione_prov2005/

ISPRA, 2009. La disaggregazione a livello provinciale dell'inventario nazionale delle emissioni. Anni 1990-1995-2000-2005. ISPRA, 92/2009. URL: http://www.isprambiente.gov.it/it/pubblicazioni/rapporti

ISPRA, several years [a]. Italian Greenhouse Gas Inventory - National Inventory Report. http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni

ISPRA, several years [b]. Quality Assurance/Quality Control plan for the Italian Emission Inventory, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni

ISPRA, several years [c]. Annuario dei dati ambientali. URL:http://annuario.isprambiente.it/

ISPRA, several years [d]. Serie storiche delle emissioni nazionali di inquinanti atmosferici, Rete del Sistema Informativo Nazionale Ambientale - SINANET. URL: http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni

Jenkins B.M. (1996a). 'Atmospheric Pollutant Emission Factors from Open Burning of Agricultural and Forest Biomass by Wind Tunnel Simulations'. Final report (3 Vols.). CARB Project A932-126, California Air Resources Board, Sacramento, California.

MATTM, several years [b]. Personal communication: E-mail request for sewage sludge applied to agricultural soils in Italy. Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Roma –Italia

Perelli, M., 2007. Prezzi dei prodotti agricoli e fertilizzazione. Fertilizzanti Maggio 2007. Anno IX N3. 10-13pp

Regione Emilia Romagna, 2004 L. R. 28/98 – P.S.A. 2001 - N. PROG. 3 TAB. B3 - Bilancio dell'azoto nelle specie di interesse zootecnico, Relazione finale, a cura di C.R.P.A., September 2004, Reggio Emilia, Italy

Xiccato G., Schiavon S., Gallo L., Bailoni L., Bittante G., 2005. Nitrogen excretion in dairy cow, beef and veal cattle, pig, and rabbit farms in Northern Italy. Ital. J.Anim.Sci. Vol. 4 (Suppl.), 103-111.

10.7 Waste (NRF sector 5)

AMA-Comune di Roma, 1996. Nuovo impianto per l'incenerimento dei rifiuti ospedalieri. Rapporto AMA.

ANPA, 1998. Il sistema ANPA di contabilità dei rifiuti, prime elaborazioni dei dati. Agenzia Nazionale per la Protezione dell'Ambiente.

APAT-ONR, several years. Rapporto Rifiuti. Agenzia per la Protezione dell'Ambiente e per i servizi

Tecnici.

AUSITRA-Assoambiente, 1995. Impianti di trattamento dei rifiuti solidi urbani e assimilabili. Indagine a cura di Merzagora W., Ferrari S.P.

Borgioli E., 1981. Nutrizione e alimentazione degli animali domestici. Ed Agricole, p. 464.

CESTAAT, 1988. Impieghi dei sottoprodotti agricoli ed agroindustriali, Vol. 1. Centro Studi sull'Agricoltura, l'Ambiente e il Territorio, edizione fuori commercio, p. 311.

De Stefanis P., 1999. Personal communication.

De Stefanis P., 2012. Personal communication (mail 16 November 2012)

EMEP/CORINAIR, 2007. Atmospheric Emission Inventory Guidebook. Technical report No 16/2007.

EMEP/EEA, 2009. Air Pollutant Emission Inventory Guidebook. Technical report n. 9/2009.

EMEP/EEA, 2013. Air Pollutant Emission Inventory Guidebook. Technical report n. 12/2013.

ENEA-federAmbiente, 2012. Rapporto sul recupero energetico da rifiuti urbani in Italia. 3° ed.

Favoino E., Cortellini L., 2001. Composting and biological treatment in southern European countries: an overview. Conference Proceedings Soil and Biowaste in Southern Europe. Rome 18-19 January, 2001.

Favoino E., Girò F., 2001. An assessment of effective, optimised schemes for source separation of organic waste in Mediterranean districts. Conference Proceedings Soil and Biowaste in Southern Europe. Rome 18-19 January, 2001.

FEDERAMBIENTE, 1998. Impianti di smaltimento: analisi sui termocombustori RSU – prima edizione. Indagine a cura di Motawi A.

Finn L., Spencer R., 1997. Managing biofilters for consistent odor and VOC treatment. Biocycle, January 1997 Vol. 38 Iss.1.

Gaudioso et al., 1993. Emissioni in atmosfera dalle discariche di rifiuti in Italia. RS, Rifiuti Solidi vol. VII n. 5, Sept.-Oct. 1993.

IPCC, 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories*. Three volumes: Reference Manual, Reporting Manual, Reporting Guidelines and Workbook. IPCC/OECD/IEA. IPCC WG1 Technical Support Unit, Hadley Centre, Meteorological Centre, Meteorological Office, Bracknell, UK.

IPCC, 2000. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit, Hayama, Kanagawa, Japan.

ISPRA, 2017[a]. Italian Greenhouse Gas Inventory 1990-2014. National Inventory Report 2016. March 2016, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni .

ISPRA, several years [a]. Rapporto Rifiuti. Istituto Superiore per la Protezione e la Ricerca Ambientale. http://www.isprambiente.gov.it/it/pubblicazioni/rapporti

ISPRA, several years [b]. Gli indicatori del clima in Italia nel 2015. Anno XI. http://www.scia.isprambiente.it/Documentazione/RAPPORTOCLIMA2015.pdf

ISTAT, several years [a]. Statistiche dell'agricoltura, zootecnia e mezzi di produzione - Annuari (1990-1993), Istituto Nazionale di Statistica.

ISTAT, several years [b]. Statistiche dell'agricoltura - Annuari (1994-2000), Istituto Nazionale di Statistica.

ISTAT, 2016[a]. Dati congiunturali sulle coltivazioni 2014. Istituto Nazionale di Statistica. http://agri.istat.it/jsp/Introduzione.jsp.

ISTAT, 2016[b]. Personal communication with R. Moro: E-mail request for last updated information on agricultural surface and production, year 2015. Istituto Nazionale di Statistica.

MATTM, several years [a]. RSA - Rapporto sullo stato dell'ambiente 1989, 1992, 1997, 2001. Ministero dell'Ambiente e della Tutela del Territorio e del Mare.

Ministerial Decree 19 November 1997, n. 503. Regolamento recante norme per l'attuazione delle Direttive 89/369/CEE e 89/429/CEE concernenti la prevenzione dell'inquinamento atmosferico provocato dagli impianti di incenerimento dei rifiuti urbani e la disciplina delle emissioni e delle condizioni di combustione degli impianti di incenerimento di rifiuti urbani, di rifiuti speciali non pericolosi, nonché di taluni rifiuti sanitari. G.U. 29 gennaio 1998, n. 23.

Ministerial Decree 12 July 1990. Linee Guida per il contenimento delle emissioni inquinanti degli impianti industriali e la fissazione dei valori minimi di emissione. G.U. 30 luglio 1990, n. 176.

Pastorelli et al., 2001. Sviluppo di fattori di emissione da inceneritori di rifiuti urbani lombardi e loro applicazione all'inventario nazionale delle diossine. Ingegneria Ambientale, ANNO XXX N.1 January 2001.

SEFIT, several years. Personal Communication with Daniele Fogli: E-mail request for activity data regarding cremation of corpses in Italy.

Tchobanoglous G. et al., 1993. Tchobanoglous G., Theisen H., Vigil A. Integrated Waste Management, McGraw-Hill, 1993.

TNO, 1995. Technical paper to the OSPARCOM-HELCOM UNECE. Emission inventory of Heavy Metals and Persistent Organic Pollutants. TNO-MEP –R 95/247, 1995.

US EPA, 1990. Air Emissions Species Manual, vol. I: Volatile Organic Compound Species Profiles, Second Edition. EPA-450/2-90-001a (United States Environmental Protection Agency – Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711), January 1990.

UWWTD, 2011. 6th UWWTD implementation report Technical assessment of information on the implementation of Council Directive 91/271/EEC of 21 May 1991 concerning Urban Waste Water Treatment, as amended by Commission Directive 98/15/EC of 27 February 1998 Situation as of 31 December 2007 or 31 December 2008. Final report as of 8 August 2011.

10.8 Recalculations and improvements

EMEP/EEA, 2016. Air Pollutant Emission Inventory Guidebook. EEA. Technical report No 21/2016.

EMISIA SA, 2016. COPERT 4 v 11.4, Computer programme to calculate emissions from road transport, September 2016. http://www.emisia.com/copert/.

ISPRA, 2017[b]. Quality Assurance/Quality Control plan for the Italian Emission Inventory. Year 2017. March 2017, http://www.sinanet.isprambiente.it/it/sinanet/serie_storiche_emissioni.

ISTAT, 2014. I consumi energetici delle famiglie, 2013. Nota metodologica. Istituto Nazionale di Statistica. http://www.istat.it .

10.9 Projections

Amann, M., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Höglund-Isaksson, L., Klimont, Z., Nguyen, B., Posch, M., Rafaj, P., Sandler, R., Schöpp, W., Wagner, F., Winiwarter, W., 2011. Cost-effective control of air quality and greenhouse gases in Europe: Modeling and policy applications. Environmental Modelling & Software 26, 1489-1501.

Capros P. et al., 2016. EU Reference Scenario 2016 - Energy, transport and GHG emissions - Trends to 2050. European Union, 2016. https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf

Caputo A., Colaiezzi M., Contaldi M., Pantaleoni M., Peschi E., 2015. Scenari di consumi elettrici al 2050. ISPRA Technical Report 213/2015.

Ciucci, A., D'Elia, I., Wagner, F., Sander, R., Ciancarella, L., Zanini, G., Schöpp, W., 2016. Cost-effective reductions of PM2.5 concentrations and exposure in Italy. Atmospheric Environment, 140, 84-93.

D'Elia, I., Bencardino, M., Ciancarella, L., Contaldi, M., Vialetto, G., 2009. Technical and Non-technical measures for air pollution emission reduction: The integrated assessment of the Regional Air Quality Management Plans through the Italian national model. Atmospheric Environment, 43, 6182-6189.

D'Elia, I., Peschi, E., 2013. Lo scenario emissivo nazionale nella negoziazione internazionale. ENEA Technical Report, RT/2013/10/ENEA (in Italian).

D'Elia, I., Peschi, E., 2016. How National integrated air quality models can be used in defining environmental policies: the revision of the NEC directive. ENEA Technical Report, RT/2016/30/ENEA

EC, 2016. Directive (EU) 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC. Official Journal of the European Union L. 344/1 of 17.12.2016.

Loulou, R., Goldstein, G., Noble, K., 2004. Documentation for the MARKAL Family of Models. ETSAP.

Loulou, R., Remne, U., Kanudia, A., Lehtila, A., Goldstein, G., 2005. Documentation for the TIMES Model - PART I 1–78.

Mircea M., Ciancarella L., Briganti G., Calori G., Cappelletti A., Cionni I., Costa M., Cremona G., D'Isidoro M., Finardi, S., Pace G., Piersanti A., Righini G., Silibello C., Vitali L., Zanini G., 2014. Assessment of the AMS-MINNI system capabilities to simulate air quality over Italy for the calendar year 2005. Atmospheric Environment 84, 178-188.