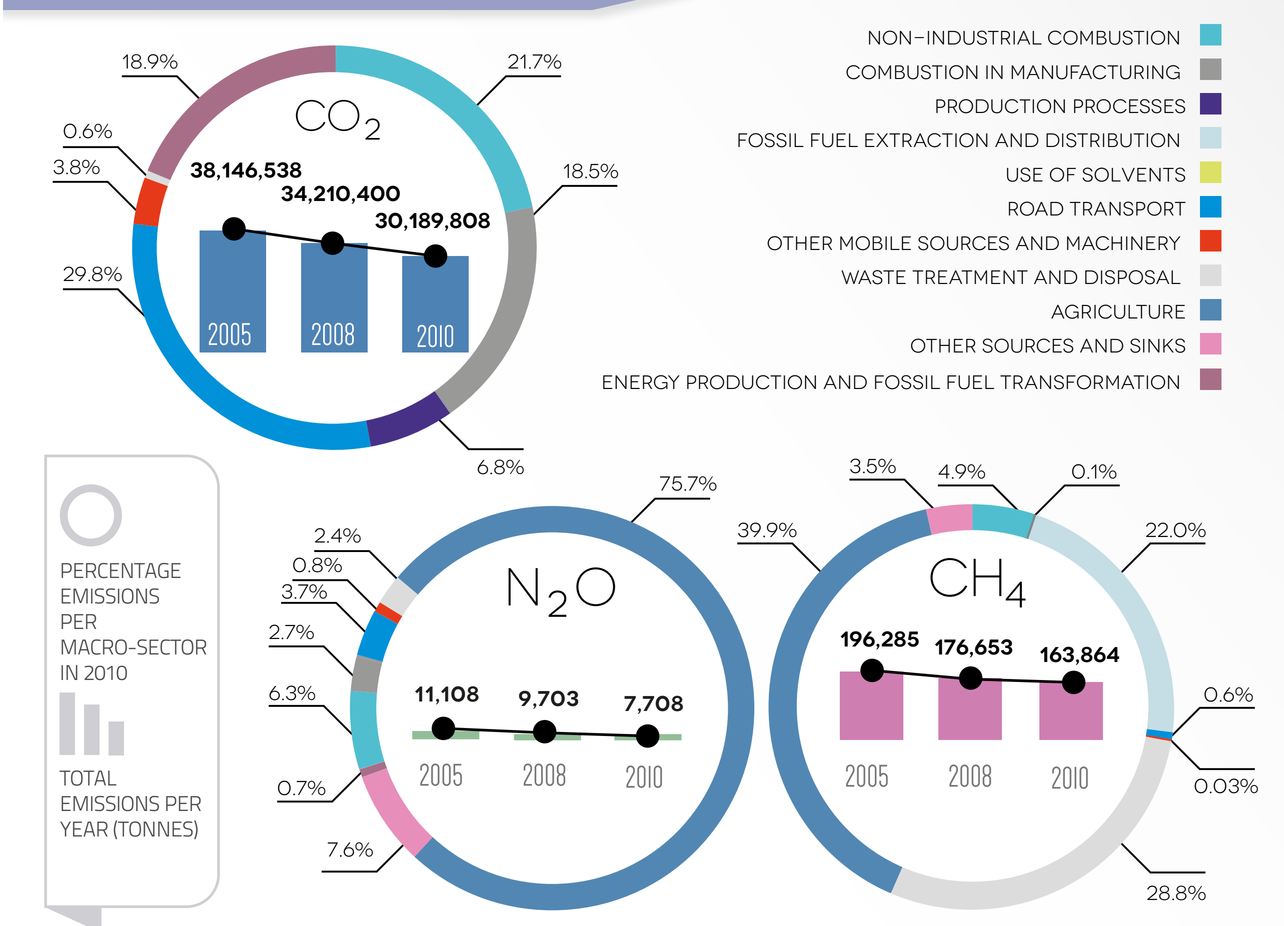
Cap.13 - Air in Veneto: from Quality Assessment to Emissions Control

In this chapter, we focus on the so-called greenhouse gases and on suspended particulate matter. Greenhouse gases are present in the atmosphere and have the characteristic of being able to withhold the earth's outgoing infrared radiation in significant quantities, contributing to maintaining a certain temperature, reducing heat dispersion that would otherwise make the air a lot colder. These gases originate in part naturally and in part as a side effect of human activity.
With regard to suspended particulate matter, however, these are composed of solid and liquid atmospheric particles suspended in the air, of different sizes, chemical compositions and origins. Some of these particles are emitted directly as they are from different natural and human sources and are defined as "primary particles", whilst others are derived from a series of chemical and physical reactions that occur in the atmosphere and are called "secondary particles".
The situation concerning the emission of greenhouse gases and particulates in Veneto in the period 2005-2010 improved slightly, although the air pollution situation remains difficult. As well as emissions pure and simple, this situation is also affected by the climate of the area in which the region is located, characterised by poor air exchange and, therefore, air stagnation.

GREENHOUSE GAS EMISSIONS



refore, the prevention and reduction of emissions is important even where recorded concentrations are low, insofar as the pollutants produced in such areas may be contaminating other areas far away.
The pollution of a certain area may also be caused by another important factor: air stagnation, which, especially on valley floors, such as in the Po Valley in Italy, leads to the accumulation of pollutants caused by strong thermal inversions in the winter months, in particular during periods of high pressure and low rainfall. It is clear, therefore, that meteorological conditions assume an important role in the study of air pollution.
On a local level, the problem concerns urban pollution, caused by heating in buildings, road traffic and industrial and energy plants. Indeed, towns and cities are the places in which we find the highest concentrations of sources of environmental imbalance, which directly affects the health of residents.
In this chapter, we focus on the so-called greenhouse gases and on suspended particulate matter (SPM). Greenhouse gases are present in the atmosphere, transparent to solar radiation entering the Earth's atmosphere, but capable of withholding significant quantities of outgoing infrared radiation. Thus, greenhouse gases contribute to maintaining a certain temperature on Earth, reducing heat dispersion, which otherwise would make it much colder, by creating, in fact, a greenhouse effect. These gases originate in part naturally and in part as a side effect of human activity. With regard to suspended particulate matter, however, these are composed of solid and liquid atmospheric particles suspended in the air, of different sizes, chemical compositions and origins. Some of these particles are emitted directly as they are from different natural and human sources and are defined as "primary particles", whilst others are derived from a series of chemical and physical reactions that occur in the atmosphere and are called "secondary particles".

13.1 Greenhouse Gases

In this sub-chapter, we focus on greenhouse gases, which, as mentioned earlier, are mostly naturally present in the atmosphere and, to a lesser degree, are created by human activity.
The impact of a gas on the greenhouse effect is derived from multiple factors: its radiative forcing, its concentration and the time it spends in the atmosphere.

IThe Global Warming Potential of a greenhouse gas

In particular, the Global Warming Potential (GWP) represents the combined effect of the time spent in the atmosphere of each gas and the relative specific effectiveness in absorbing infrared radiation emitted by the Earth. Therefore, GWP is a measure of how much a greenhouse gas contributes to global warming in relation to CO_2. GWPs are calculated by the Intergovernmental Panel on Climate Change (IPCC) and are used as conversion factors for calculating the emissions of all the greenhouse gases in CO_2 equivalents. The most important greenhouse gases present in the atmosphere are water vapour (H^2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH^4) and sulphur hexafluoride (SF^6). As well as these, there are others that originate exclusively from human activity and which form part of the halocarbon category, i.e. containing chlorine or fluorine and whose emissions are regulated by Montreal Protocol, an international treaty signed on 16 September 1987, entering into force on 1 January 1989 and reviewed subsequently on the occasion of the Conference of the Parties in London in 1990, in Copenhagen in 1992, in Vienna in 1995, again in Montreal in 1997 and in Beijing in 1999. These gases are produced in much lower quantities than CO_2, CH4 and N_2O and have much lower atmospheric concentrations; however, they can have much longer lifetimes and much higher radiative forcing, between 3,000 and 13,000 times that of CO_2.
Considering all of the above, it is clear how the GWP of a gas, together with its atmospheric concentration, determines its contribution to the greenhouse effect. Therefore, it can be understood how the various gases that make up the atmosphere don't all contribute to creating the greenhouse effect in the same way: for example, molecules such as nitrogen (N_2) or oxygen (O_2), despite forming 98% of our atmosphere, are not capable of absorbing much radiation. The gases responsible for the greenhouse effect are those equipped with an asymmetric molecular structure, such as methane (CH^4), ozone (O_2), water vapour (H_2O), nitrous oxide (N_2O) and fluorinated gases.
An aside must be made for carbon dioxide (CO^2), which, despite not having a high GWP, is however present in the atmosphere in much higher concen-

trations that other gases that perhaps have significantly higher GWPs and, for this reason, it is considered one of the main causes of the greenhouse effect. It interacts with the atmosphere through both natural absorption and emission processes and processes determined by human activity. In reality, the latter are much more limited in quantity than natural processes but, all the same, prove sufficient to alter the balance of the whole system. As a result of this alteration, CO_2 tends to accumulate in the atmosphere, due to the fact that the absorption processes by the oceans are unable to compensate fully for the inflow of carbon (C). The main causes of emissions due to human activity are the use of energy from fossil fuels, i.e. petroleum, carbon and natural gas, which tend to increase the concentrations of CO_2, as well as deforestation and the changes in use of agricultural land, which, at the same time, tends to reduce the planet's absorption capacity.
Methane (CH_4) is produced by the anaerobic decomposition of organic material and is currently deemed responsible for around 8% of the greenhouse effect. Its heat retention capacity is over 20 times that of carbon dioxide. Its average atmospheric concentration is increasing at an estimated rate of between 1.1% and 1.4%. The main sources of methane are marshlands, paddy fields, the fermentation of organic fertiliser, biomass combustion, the production and distribution of natural gas, carbon extraction and termites. In terms of the most recent trends, there has been an increase in emissions of methane from landfills and from the energy sector and, at the same time, a reduction in emissions from the agricultural sector.
Finally, nitrous oxide (N_2O) has a fairly low atmospheric concentration of around 1,000 times less than CO_2, however it is over 300 times more powerful in retaining heat. Despite being present in limited quantities, there has been an increase in nitrous oxide over the past few decades, going from 275 parts per billion (ppb) in the pre-industrial period to 312 ppb at the end of the last century. The majority of nitrous oxide in the atmosphere is derived from microbiological processes. In land and water, the leading sources of N_2O emissions are nitrification and denitrification.
In Italy, as far as reducing greenhouse gas emissions is concerned, the implementing provisions of the EC Directive relating to the EU Emissions Trading System are in force: Law No. 316 of 30/12/2004 (implementation of Directive 2003/87/CE) and Legislative Decree No. 30/2013 (implementation of Directive 2009/29/CE).

In light of that revealed up to now, it emerges that control over greenhouse gases is particularly important in order to render air quality restoration policies coherent with policies on tackling climate change. This sub-chapter focuses on the greenhouse gas emissions estimates in Veneto according to productive sector. It focuses on three greenhouse gases in particular: CO_2, CH_4 and N_2O.
INEMAR, the regional atmospheric emissions inventory
Emissions estimates for the main greenhouse gases (CH_4, CO_2, N_2O) in reference to the Veneto region are extrapolated by the regional atmospheric emissions inventory, hereinafter "INEMAR Veneto", managed by the Regional Agency for Environmental Prevention and Protection in Veneto (ARPA Veneto), commissioned by the Regional Administration.
The inventory is one of the cognitive support tools for the management of air quality on a regional level, insofar as it gathers together in a single database atmospheric emissions estimates in a defined spatial/temporal unit, grouped together according to activity (e.g. transport, livestock farming, manufacturing), territorial unit (e.g. region, province, municipality) and temporal unit (year, month, hour, etc.), fuel used (petrol, diesel, methane, etc.), pollutant (NOx, CO, etc.) and type of emission (point source, diffuse, etc.).
In Veneto, the IT tool used to fill the regional atmospheric emissions inventory is the INEMAR database (INventario EMissioni ARia; Atmospheric Emissions Inventory). Indeed, the Regional Administration signed an inter-regional agreement for the use and development of the INEMAR database, shared with other Italian regions, in particular those belonging to the BPA (Po-Adriatic Basin), an area of northern Italian territory in which there are frequent occurrences of severe atmospheric pollution, with particular focus on the atmospheric concentrations of fine particulate matter (PM104, PM2.5) in the winter and of ozone (O_3) in the summer.
INEMAR Veneto was initially developed as part of a series of cooperation agreements on the subject of atmospheric pollution, which, starting in 2005, involved the BPA regions, including Veneto. Subsequently, Legislative Decree 155/2010, the decree implementing EC Directive 2008/50/CE, made it compulsory for all Italian regions to draft an atmospheric emissions inventory to be updated periodi-

cally every three years and also at the time of the provincial scaling of the national atmospheric emissions inventory managed by the ISPRA, Higher Institute for Environmental Protection and Research, i.e. every five years.

INEMAR, the regional atmospheric emissions inventory

Emissions estimates in the regional inventory are classified according to SNAP97 Activity and the estimates are made in reference to the CORINAIR guidelines, with additional regional studies and surveys, and periodically updated in relation to the available edition of the Emission Inventory Guidebook EMEP/EEA. As well as macro-pollutants of interest in terms of atmospheric pollution problems (TSP, PM_{10}, $PM_{2.5}$, NOx, SO2, CO, VOC, NH3), INEMAR Veneto also includes emissions estimates of the three greenhouse gases: CH_4, CO, CO_2, N_2O for the main SNAP97 activities. In particular, in the latest edition of INEMAR Veneto, which provides an evaluation of the emissions produced in 2010 in the Veneto region, divides the estimates into 210 activities.

The results of greenhouse gas emissions monitoring in Veneto

30 million tonnes of CO2, 164,000 of methane and 7,700 of nitrous oxide were emitted by Veneto in 2010

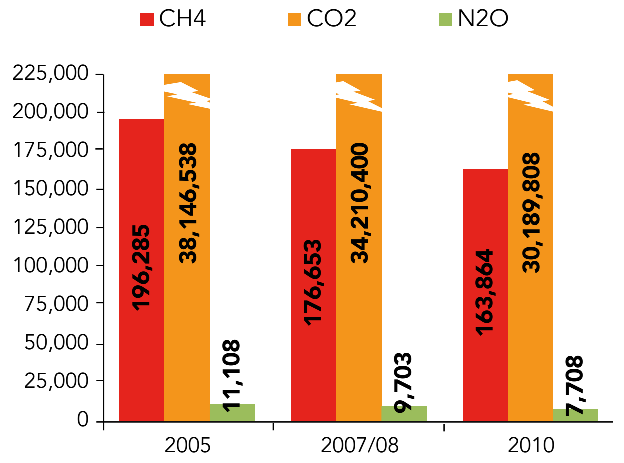
Moving on to the analysis of data gathered in the INEMAR inventory in the three data collection periods, 2005, 2007/08 and 2010, we can see how CO_2 emissions are far greater than those in the other greenhouse gases examined, with over 30 million tonnes in Veneto in 2010, against 164,000 tonnes of methane and 7,700 tonnes of nitrous oxide.
Observing the trend in the greenhouse gases examined over the course of the three years of data

Tab. 13.1.1 - List of SNAP97 activities whose emissions were estimated in the 2010 edition of INEMAR Veneto (*)

Code	Macro-sector	no. of Sectors	no. of Activities
01	Combustion in energy and transformation industries	4	9
02	Non-industrial combustion plants	3	8
03	Combustion in manufacturing industry	2	18
04	Production processes	6	34
05	Extraction & distribution of fossil fuels and geothermal energy	2	3
06	Solvent and other product use	4	24
07	Road transport	5	14
08	Other mobile sources and machinery	9	14
09	Waste treatment and disposal	4	14
10	Agriculture	7	50
11	Other sources and sinks	7	22
Total		**53**	**210**

(*) *Classification according to SNAP97 activity (Selected Nomenclature for Air Pollution) envisaged by the CORINAIR Project (COordination Information AIR) promoted by the European Union an developed by the European Environmental Agency with the objective of gathering data and information on pollutant emissions in EU countries.*

Fig. 13.1.1 – Emissions of CH_4, CO_2, N_2O in Veneto (tonnes/year) – Years 2005, 2007/8 and 2010



Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2005, 2007/8 and 2010.

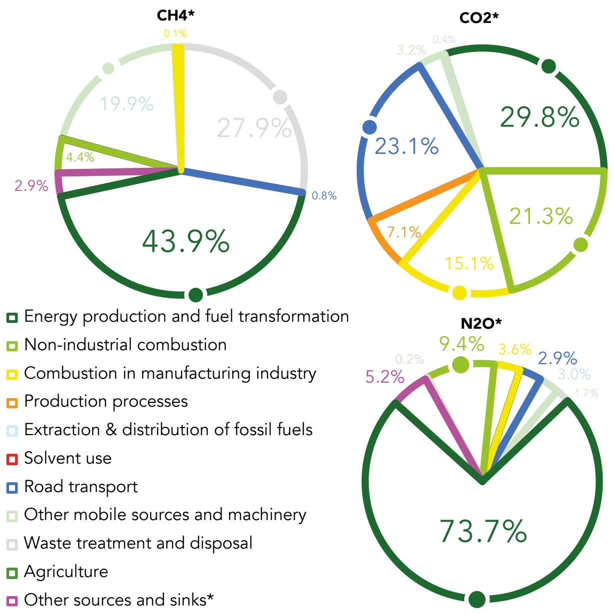
Tab 13.1.2 – Emissions of CH_4, CO_2, N_2O in Veneto (% variations) – Years 2007/8 – 2005, 2010-2007/08

	2007-08/05	2010/2007-08	2010/2005
CH4	-10.0	-7.2	-16.5
CO2	-10.3	-11.8	-20.9
N2O	-12.6	-20.6	-30.6

Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2005, 2007/8 and 2010.

collection, we can see a progressive and encouraging fall in emissions. In particular, methane reduced by 10% from 2005 to 2007/08 and by a further 7.2% from 2007/08 to 2010, with an overall variation from 2005 to 2010 of 16.5%.
Carbon dioxide followed a similar trend to methane in the first two years of data collection, with a reduction of 10.3% from 2005 to 2007/08; however, it then fell more sharply in 2010, by almost 12%, creating a decrease of almost 21% over the entire survey period.
Finally, nitrous oxide also decreased gradually over the years, but with more significant variations as compared to the other two greenhouse gases, with -12.6% and -20.6% from 2005 to 2007/08 and 2007/08 to 2010 respectively. Thanks to this second decrease, the overall reduction in N2O emissions was 30.6% between 2005 and 2010.
From the analysis of the macro-sectors that contribute to greenhouse gas emissions, we can see how the distributions are different for each of the three gases under consideration: for methane, the sector with the highest emissions is agriculture, with values fluctuating from 43.9% to 39.9% in 2005 and 2010 respectively. For nitrous oxide, distribution of emissions remains essentially stable over time, with agriculture the leading sector with percentages always above 73%.

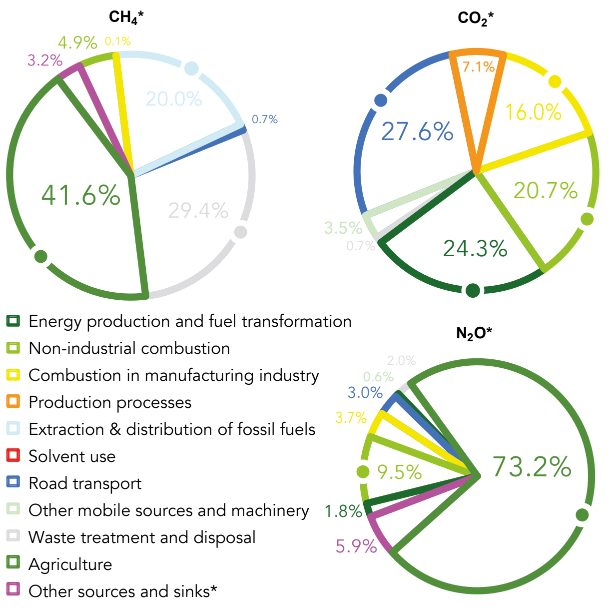
Fig.13.1.2 – Emissions of CH_4, CO_2, N_2O according to SNAP97 macro-sector in Veneto (% values) – Year 2005



(*) The macro-sectors missing in the figure do not present emissions relative to pollution
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2007/08

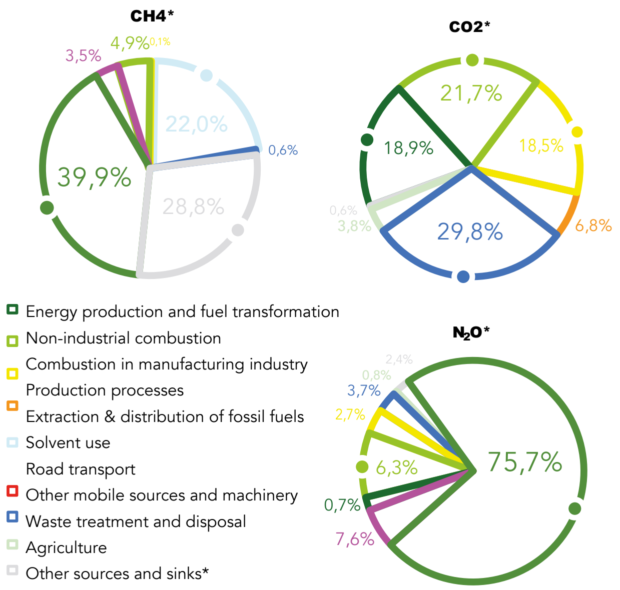
Carbon dioxide is worth a separate mention: in 2005, the leading macro-sector in terms of emissions was the energy production sector, which, however, recorded a significant decrease in the period under examination (indeed, gross production of electricity in Veneto fell by 36.5% between 2005 and 2010). At the same time as the drop in CO_2 emissions in the energy sector, there was a recorded slight increase within the transport sector, and the sum of these two events led to the transport sector overtaking the energy sector, reaching 29.8% of overall CO_2 emissions, as compared to 23.1% in 2005.

Fig. 13.1.3 – Emissions of CH_4, CO_2, N_2O according to SNAP97 macro-sector in Veneto (% values) – Year 2007/08



(*) The macro-sectors missing in the figure do not present emissions relative to pollution
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2007/08

Fig. 13.1.4 – Emissions of CH_4, CO_2, N_2O according to SNAP97 macro-sector in Veneto (% values) – Year 2010



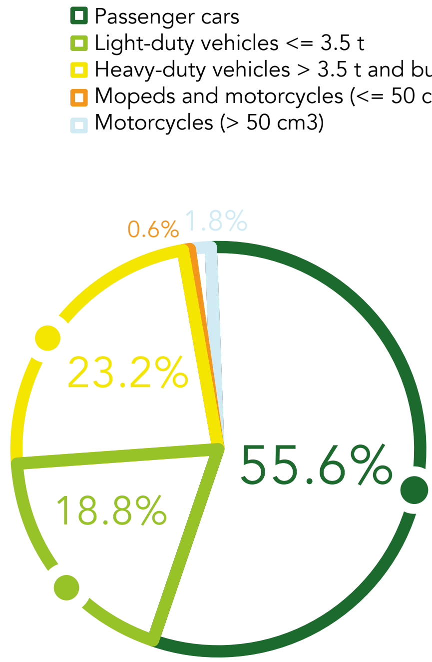
(*) The macro-sectors missing in the figure do not present emissions relative to pollution
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2007/08

Focusing our attention on 2010, it is interesting to analyse the distribution of emissions contributions in relation to the SNAP97 sectors within the macro-sectors identified as being mainly responsible for the greenhouse gas emissions estimates in the Veneto regional inventory.

Transport is the sector with the highest CO_2 emissions…

As far as carbon dioxide is concerned, the macro-sector with the highest emissions was the road transport sector: within this sector, passenger cars are the worst culprits with 56% of emissions, followed by heavy-duty vehicles with 23% and light-duty vehicles with almost 19%.

Fig. 13.1.5 – Road transport macro-sector: CO_2 emissions per sector (thousands of tonnes/year). Veneto – Year 2010

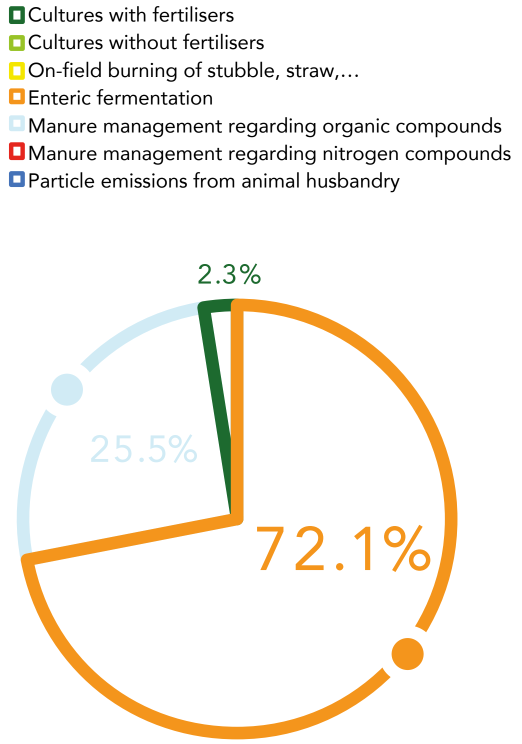


Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

This data is certainly affected more by the high number of passenger cars in circulation than by the pollution caused by individual vehicles, which, thanks to recent technology, have increasingly low average levels of pollution. In this sense, the strategy identified for limiting CO_2 emissions involves, as well as further improvement to engine efficiency, a reduction in traffic thanks to the enhancement of public services, the practice of car-sharing and

car-pooling and the increased use of eco-friendly transport, such as bicycles, in urban centres and whenever possible.
It is to be reminded that the emissions estimates found in INEMAR Veneto for the road transport ma-cro- sector are from ISPRA.

Fig. 13.1.6 – Agriculture macro-sector: CH_4 emissions according to sector* (tonnes/year). Veneto – Year 2010

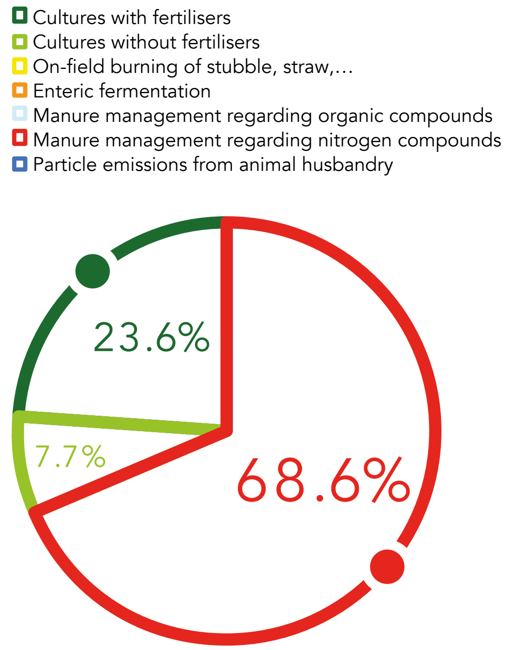


(*) The sectors "cultures without fertilisers", "on-field burning of stubble, straw", "manure management regarding nitrogen compounds and "particle emissions from animal husbandry" present either zero or insignificant levels of CH4 emissions into the atmosphere
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

...and agriculture is the sector with the highest methane and nitrous oxide emissions

With regard to methane, the macro-sector with the highest overall emissions is agriculture. Within this sector, there are two sub-sectors that, together, produce over 97% of the total methane produced by agriculture: enteric fermentation, with over 72%, and manure management regarding organic compounds, with 25.5%. Agriculture is also the sector with the highest nitrous oxide emissions, although, in contrast to methane, the sub-sector that produces the most nitrous oxide is manure management regarding nitrogen compounds, with almost 70% of overall agricultural emissions, followed by cultures with fertilisers, at around 24%.

Fig. 13.1.7 – Agriculture macro-sector: NO_2 emissions according to sector* (tonnes/year). Veneto – Year 2010



(*) The sectors "on-field burning of stubble, straw", "enteric fermentation", "manure management regarding organic compounds and "particle emissions from animal husbandry" present either zero or insignificant levels of NO_2 emissions into the atmosphere
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

Further to individual analysis of carbon dioxide, methane and nitrous oxide, the three gases can be considered as a group, creating cumulative emissions data using appropriate standardisation coefficients in order to create a single unit of measurement and thus be able to combine the emissions of the three gases in one sum total. These coefficients are conversion factors used to measure the capacity of a certain gas to absorb thermal radiation

over a certain time relative to the absorption by an equal quantity of CO_2 (carbon dioxide is taken as reference, therefore assigned a coefficient of 1). These coefficients are called Global Warming Potential (GWP). As is shown below, methane has a GWP of 21 times that of carbon dioxide, whilst that of nitrous oxide is 310 times that of CO_2.
Based on these GWPs, the capacities of the three greenhouse gases are recalculated and added together to obtain an overview of greenhouse gas emissions in Veneto during the three years of the survey. It is to be pointed out that, despite the high potential of methane and the yet higher potential of nitrous oxide, carbon dioxide is present in such high quantities as to compensate for its lower GWP and result in higher emissions than both of the other two gases.

Overall CO_2 equivalent emissions are decreasing

Overall CO_2 equivalent emissions are decreasing
The trend in overall emissions is gradually falling, thus demonstrating encouraging developments. In addition, as is the case with CO_2, the sector with the strongest impact changed over the three years: in 2005, it was the energy production sector, with over 12.2 million tonnes of emissions a year, whilst, in 2007/08 and in 2010, following a contraction in the energy sector, road transport became the biggest culprit, with 10.2 and 9.8 million tonnes a year respectively.
Focusing on road transport, the macro-sector with the highest CO_2 equivalent emissions in 2010, we find confirmation of that which is also highlighted in the case of carbon dioxide, i.e. the highest emissions are created by passenger cars, which, alone, produce almost 5.5 million tonnes of CO_2 equivalent a year, almost 56% of the whole macro-sector. The second highest greenhouse gas emissions are produced by heavy-duty vehicles (above 3.5 tonnes and buses), which, with 2.3 million tonnes, emit 23.2% of all CO_2 equivalent produced by road transport. In third place, we find light-duty vehicles (under 3.5 tonnes), which produce 18.7% of all road transport emissions.
Going into further detail within the road transport sector, we find three macro types of road on which most traffic is concentrated: highways, rural roads and urban roads. From the data, it emerges that the greatest emissions are produced on rural roads, with almost 41%, followed by urban roads and highways, which have almost equal shares of 29.6% and 29.4%. The high emissions on rural roads may be explained by the significant quantity of traffic and the higher average number of km/car travelled by each vehicle.

Tab. 13.1.3 – The Global Warming Potential (GWP*) of CH_4, CO_2 and N_2O: conversion factors in CO2 equivalent

Name	Symbol	GWP
Methane	CH_4	21
Carbon dioxide	CO_2	1
Nitrous oxide	N_2O	310

** Global Warming Potential (GWP) is defined by the Intergovernmental Panel on Climate Change (IPCC) as an indicator that measures the capacity of absorption of thermal radiation by a greenhouse gas over a certain period of time (e.g. 100 years, GWP100) relative to the absorption by an equal quantity of CO_2 (taken as reference and thus assigned a GWP of 1). GWPs are used as conversion factors to calculate the emissions of all greenhouse gases in CO_2 equivalents.*

Source: Intergovernmental Panel on Climate Change (IPCC)

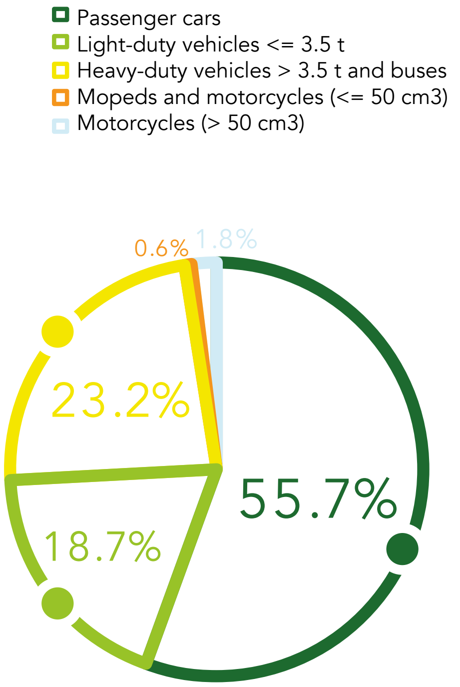
Indeed, each car, although in a higher gear than that typically used on urban roads, and thus operating at a more efficient engine regime, with lower emissions per km, travels much greater average distances per individual journey as compared to the typical journey in an urban context, compensating for and indeed surpassing the average total emissions per journey on urban roads.
In conclusion, this analysis demonstrates that the situation concerning the emission of greenhouse gases and particulates in Veneto in the period 2005-2010 improved, although the air pollution situation remains difficult. As well as emissions pure and simple, this situation is also affected by the climate of the area in which the region is located, characterised by poor air exchange and, therefore, air stagnation, which is often prolonged over quite long periods during the year.
Three greenhouse gases were analysed – carbon dioxide, methane and nitrous oxide – characterised by different emissions sources. Whilst methane and nitrous oxide display much higher GWPs, the very high quantities of carbon dioxide make it the leading culprit in terms of the greenhouse effect. In fact, by converting the three gases above into CO_2 equivalent and adding together their emissions,

Tab. 13.1.4 - Overall emissions of CO_2 equivalent (tonnes/year*) – Years 2005, 2007/08 and 2010

Macro-sector code	Macro-sector description	2005	2007/08	2010
1	Energy production and fuel transformation	12,241,937	8,948,030	6,166,540
2	Non-industrial combustion	9,222,918	8,045,838	7,371,097
3	Combustion in manufacturing	6,339,612	5,983,911	6,096,642
4	Production processes	2,898,527	2,599,635	2,223,937
5	Extraction & distribution of fossil fuels	820,344	743,194	758,072
6	Solvent use	0	0	0
7	Road transport	9,615,307	10,183,993	9,801,259
8	Other mobile sources and machinery	1,414,634	1,306,958	1,241,774
9	Waste treatment and disposal	1,367,124	1,416,722	1,241,071
10	Agriculture	4,348,712	3,760,012	3,182,717
11	Other sources and sinks	-2,557,223	-2,060,383	-2,062,642
	Total	**45,711,892**	**40,927,911**	**36,020,468**

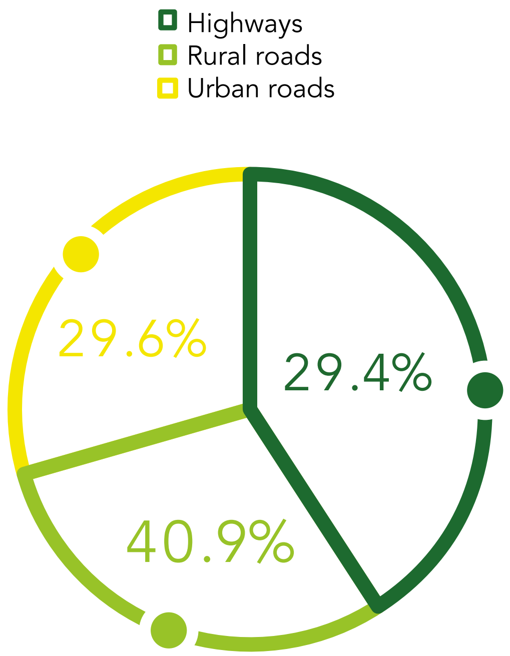
**Methane (CH_4) and nitrous oxide (N_2O) were converted into CO_2 equivalent using their respective conversion factors (GWP) and then added together as CO_2 equivalent*
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2005, 2007/08 and 2010.

Fig.13.1.8 – Road Transport macro-sector: emissions of CO_2 equivalent according to sector (tonnes/year). Veneto – Year 2010



Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

Fig. 13.1.9 – Passenger car sector: emissions of CO_2 equivalent according to activity* (tonnes/year). Veneto – Year 2010



(*) In this case, activity is understood to mean type of road on which the passenger car traffic travels
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

the resulting Global Warming Potential displays the CO_2 characteristics in terms of SNAP macro-sector distribution.
Within this context, the critical nature of road transport is confirmed, with the need for particular attention on passenger cars, which, despite presenting lower emissions factors than light-duty and heavy-duty commercial vehicles, represent the majority of traffic in circulation and produce almost 56% of regional CO2 equivalent.

13.2 Particulates

Among the SPM mentioned at the start of this chapter, there are certain particularly fine types of particulate matter, with a diameter of less than 10 µm (micrometres), called PM_{10}, or inhalable particulate, insofar as it is able to penetrate the respiratory system. In addition to PM_{10} particles, there is also a certain sub-group with diameter under 2.5 µm, called $PM_{2.5}$. As well as penetrating the respiratory system, these are also able to infiltrate the lower respiratory tract, thus resulting even more dangerous than PM_{10} particles. The main sources of PM_{10} and $PM_{2.5}$ are the different types of combustion, including those relating to energy production, transport and industrial processes, as well as the combustion of agricultural residues. In urban centres, the two main sources of pollution by fine particulates are domestic heating systems and traffic. Fine particulates PM_{10} and $PM_{2.5}$ are currently the most problematic form of atmospheric pollution, insofar as the values recorded in large parts of Europe are well above the limits established by the European Union. Italy, together with Poland, Slovakia, Turkey and the Balkans are among the European countries with the most complex situations, having exceeded the PM_{10} and $PM_{2.5}$ limits most often. In particular, the Po Valley is one of the most extensive areas displaying a particularly critical environmental situation. The regulatory reference on air quality in Italy is Legislative Decree 155 of 13 August 2010, implementing Art.10, Annex B of Law No. 88 of 7 July 2009, which delegates the government to implement EC Directive 2008/50/CE relating to "environmental air quality and for cleaner air in Europe" and which replaces the provisions of Directive 2004/107/CE. The objective of Legislative Decree 155/2010 is that of allowing the regions and autonomous provinces to assess and manage air quality. The decree also includes limit values for the protection of human health and vegetation for each atmospheric pollutant, including PM10 and Pm2.5. For the former, there are two indicators: average concentration over 24 hours, which must not exceed 50 µg/m3 more than 35 times in any calendar year; and the annual average, which must not exceed 40 µg/m3. For $PM_{2.5}$, there is just one indicator, the annual average, which, starting from 1 January 2015, must not exceed 25 µg/m^3. Legislative Decree 155/2010 was amended by Legislative Decree 250/2012, which set a tolerance margin to be applied, every year, to the annual limit for $PM_{2.5}$ (25 µg/m^3). In view of the above, it is clear that control over fine particulate matter is of great importance for the purposes of correct planning aimed at reducing atmospheric pollution. Controls are undertaken using two types of observation: air quality analysis, by measuring the concentration of individual pollutants found in the air; and monitoring the emissions of pollutants. In this sub-chapter, we concentrate on the second aspect, in particular on PM_{10} and $PM_{2.5}$ emissions in Veneto according to pollutant source and production sector. As is the case with greenhouse gases, we use the data included in the INEMAR Veneto inventory. In the most recent edition of INEMAR Veneto, containing 2010 data, technical corrections were made of previous editions, including updating the Emission Factors (EF) of the creation of emissions by woody biomass in small domestic heating devices. Domestic heating, together with point-sources (industrial plants and energy production) and road traffic are the biggest sources of emissions both in terms of quantity and for their impact on air quality. Data contained in INEMAR comes from two separate types of measurement: direct measurements taken from emissions of a source of pollution and "activity" measurements, through which estimates can be made of the emissions of a certain "activity" by using "emission factors".

The Results of Monitoring Fine Particulate Matter Emissions

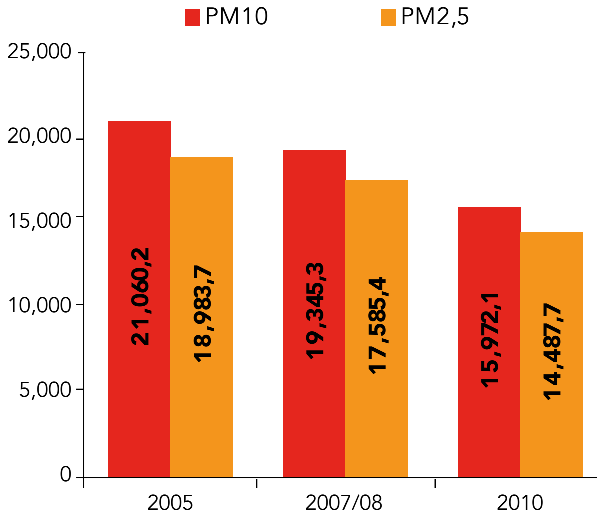
Moving on to the analysis of data gathered in the INEMAR inventory, it must be pointed out that, given the amendment of the Emission Factors (EF) in the latest edition,, 2010 estimates can no longer be directly compared to those of previous editions. ARPA Veneto thus recodified the data on a reginal level according to the new EFs, including for 2005 and 2007/08, making it possible to analyse data trends on a regional scale.

In the survey periods of 2005, 2007/08 and 2010, we can see a progressive fall in both PM_{10} and $PM_{2.5}$ emissions.

Notwithstanding the persisting situation of frequent critical issues, particularly within urban centres, there have been overall reductions in emissions of PM_{10} and $PM_{2.5}$ of 24.2% and 23.7% respectively, from 2005 to 2010. This data is certainly positive, insofar as it demonstrates and improvement in the production processes responsible for pollution, however, it must also be pondered, given the significant influence of the "financial crisis" factor. The effects of this were already felt in 2010, with a contraction in the economic activities themselves and, consequently, a relative reduction in the emission of pollutants.

From 2005 to 2010, PM10 and Pm2.5 emissions fell by24.2% and 23.7%

Fig. 13.2.1 – PM_{10} and $PM_{2.5}$ emissions in Veneto (tonnes/year) – Years 2005, 2007/08 and 2010



Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2005, 2007/08 and 2010

Analysing the different fine particulate emissions sources, we can see how, in all three of the survey periods (2005, 2007/08 and 2010), the macro-sector with the highest environmental impact is always non-industrial combustion, which includes the domestic sector and therefore residential heating: this macro-sector produced 65.4% of PM_{10} and 69.8% of $PM_{2.5}$ in 2010.

The other two macro-sectors, in decreasing order of PM_{10} and $PM_{2.5}$ emissions, are road transport and other mobile sources and machinery.

The domestic sector produces 65.4% of PM_{10} and 69.8% of $PM_{2.5}$

Agriculture is in fourth place, in which we note a clear distinction between the two types of fine particulate matter, insofar as PM_{10} emissions vary from 3.8% in 2005 to 4.1% in 2010, whilst $PM_{2.5}$ emissions are decidedly lower: 2% and 2.2% in 2005 and 2010 respectively.

Tab. 13.2.1 – PM10 and PM2.5 emissions in Veneto - % variations 2007-08/2005, 2010/2007-08, 2010/2005

	2007-08/05	2010/2007-08	2010/2005
PM_{10}	-8.1	-17.4	-24.2
$PM_{2,5}$	-7.4	-17.6	-23.7

Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2005, 2007/08 and 2010

PM_{10} and $PM_{2,5}$ emissions in Veneto (tonnes/year) - % variations 2007-08/2005, 2010/2005, 2010/2007-08

	2005	2007/08	2010
PM_{10}	21,060.2	19,345.3	15,972.1
$PM_{2,5}$	18,983.7	17,585.4	14,487.7

Source: ARPA VENETO – VENETO REGION (May 2015). INEMAR VENETO 2010 – Regional Inventory of Atmospheric Emissions in the Veneto Region, 2010 edition – final data. ARPA Veneto – Regional Air Observatory, Veneto Region, Environment Department, Environmental Protection Section, Atmospheric Protection Sector.

Looking in more detail at the macro-sector of non-industrial combustion, the sector with the most critical situation in terms of fine particulate matter emissions, it is made up of three sub-sectors: plants in agriculture, forestry and aquaculture, commercial and institutional plants and residential plants. Residential plants produce almost all the fine particulate matter of the macro-sector, with 10,430 tonnes of PM_{10} and 10,106 tonnes of $PM_{2.5}$ per year (t/y) out of a total of 1,443 and 10,119 t/y respectively.

Fig. 13.2.2 - PM_{10} and $PM_{2.5}$ emissions according to macro-sector (% values). Veneto – Year 2005 (*)

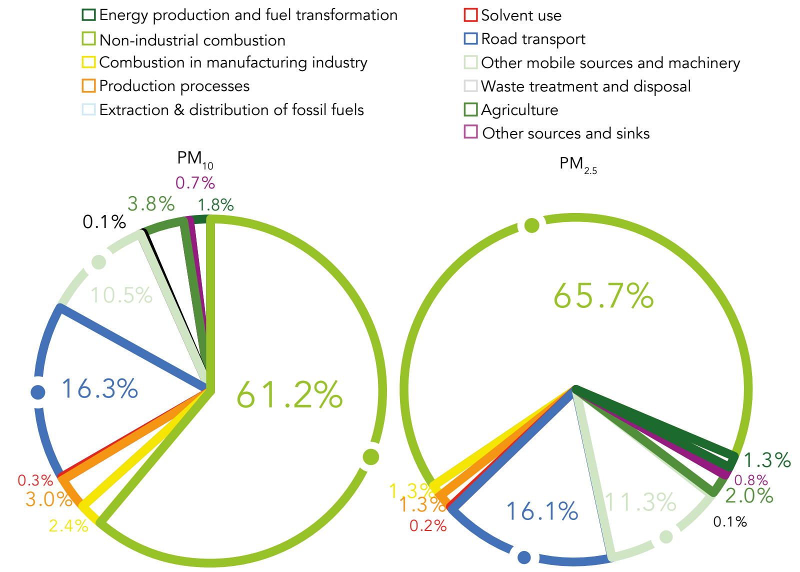


Fig. 13.2.3 - PM_{10} and $PM_{2.5}$ emissions according to macro-sector (% values). Veneto – Year 2007/08 (*)

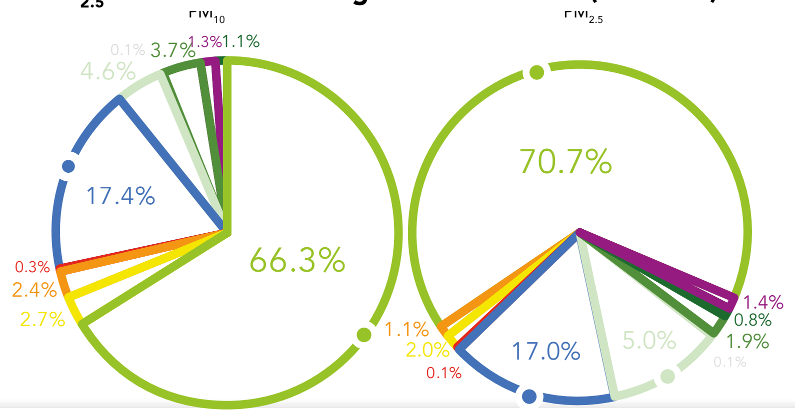
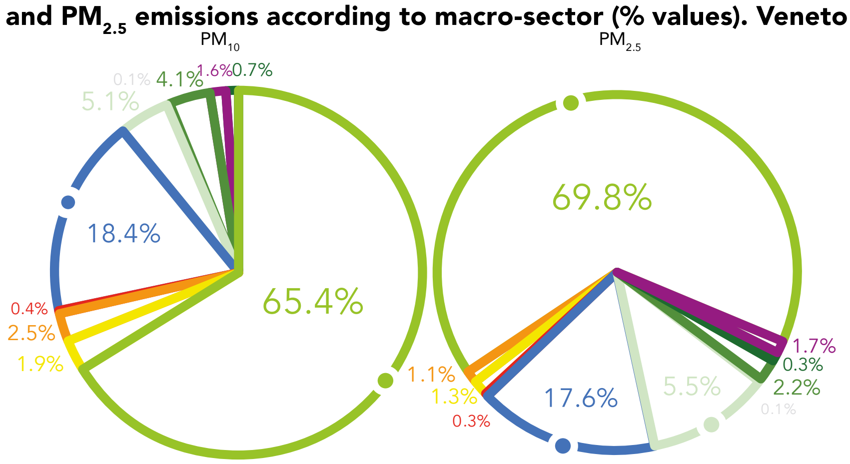


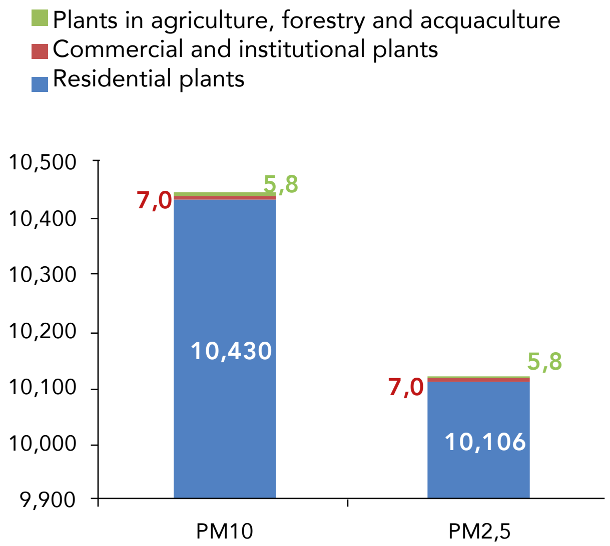
Fig. 13.2.4 –PM_{10} and $PM_{2.5}$ emissions according to macro-sector (% values). Veneto – Year 2010 (*)



(*) The macro-sector Extraction and distribution of fossil fuels has zero $PM_{2.5}$ and PM10 emissions

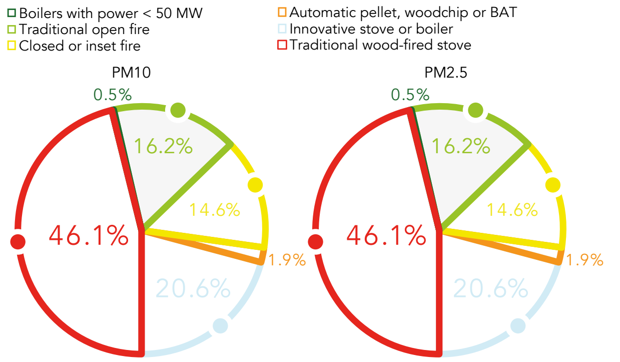
Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

Fig. 13.2.5 – Macro-sector of non-industrial combustion: PM_{10} and $PM_{2.5}$ emissions according to sector (tonnes/year). Veneto – Year 2010



Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

Fig. 13.2.6 - Residential plants sector: PM_{10} and $PM_{2.5}$ emissions according to sector (tonnes/year). Veneto – Year 2010



Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

Going into more detail within the residential plants sector, we find individual activities for the different types of heating. First and foremost, we can see that PM_{10} and $PM_{2.5}$ are almost identical in terms of emissions distribution per activity (as far as the second decimal place). The worst emissions are produced by traditional wood-fired stoves, with 46% of the overall PM_{10} and $PM_{2.5}$ of the residential heating sector. The second highest emissions are produced by more innovative stoves or boilers, with over 20.6% of the total, whilst traditional open fires are found in third place with 16.2%.

In addition to the figures demonstrating final emissions, it is also worth mentioning the emission factors of each type of heating, in order to understand better the degree of danger they pose to the environment, beyond the actual individual emissions. It is clear that open fires have the highest potential emissions, with 860 grams of PM_{10} per gigajoule of energy produced (g/Gj), more than twice that of innovative stoves or boilers or closed fires (380 g/Gj). Pellet-fired stoves have noticeably low emissions, with 76 g/Gj.

As far as PM_{10} and $PM_{2.5}$ emissions are concerned on a provincial level, we can see almost identical distribution for both pollutants: Treviso has the highest share of emissions, with around 22% of overall emissions for the region in 2010, followed by Vicenza, with almost 20%. In third place is Padua, with

Tab. 13.2.2 – INEMAR emission factors according to SNAP activity for the domestic combustion of wood (grams per gigajoule – g/Gj) – Year 2010

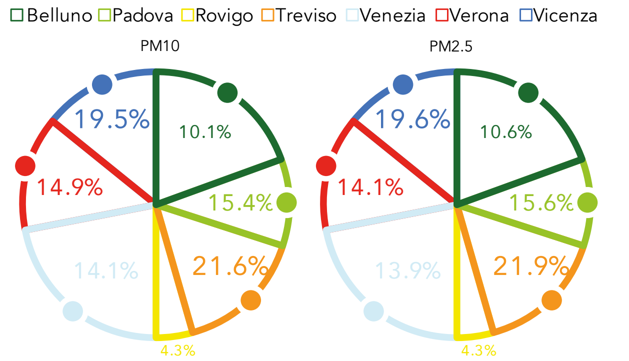
	PM_{10} (g/Gj)
Open fire	860
Traditional stove	480
Closed fire	380
Innovative stove or boiler (modern stove, majolica stove and innovative boiler)	380
Caldaia con potenza termica < 50 MW	380
Automatic pellet/woodchip-fired stove	76

Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

over 15% of the regional total, followed by Verona and Venice, with 14.9% and 14% of PM_{10} emissions and 14.1% and 13.9% of $PM_{2.5}$ emissions, respectively. Belluno is in sixth place, which, despite having a much lower population than the other five provinces, produces over 10% of the regional emissions in fine particulate matter.

This phenomenon can be explained by considering that, as seen earlier, the sector with the greatest environmental impact in terms of fine particulate matter is that of residential heating, and Belluno, due to its geographical position at the foot of the mountains, is the province with the worst climatic conditions in terms of the severity of winter: indeed, this province has the highest consumption per capita for heating and also the highest concentration of open fires, which, as we have seen, have the most elevated emission factor (860 g/Gj).

Fig. 13.2.7 - PM_{10} and $PM_{2.5}$ emissions according to province (tonnes/year) – Year 2010



Source: Veneto Region Data Processing, Regional Statistical System Section on final data of INEMAR Veneto 2010

The abovementioned consideration alters, in part, the traditional perspective of PM_{10} and $PM_{2.5}$ analysis: usually, analysis is undertaken of the concentrations detected in the atmosphere. From this type of observation, it emerges that the worst situations are found in the plain areas, due to the greater air stagnation, as well as due to increased emissions in absolute terms because of the greater concentrations in population, industrial plants and traffic. However, from the analysis above, we can see that even areas of apparently inferior pollution must be tightly monitored. Indeed, despite being characterised by lower emissions and located in more favourable areas in terms of air exchange, they hide certain critical elements that may not be very noticeable but that risk, if overlooked, harming the local air quality and damaging the surrounding environment through the transportation of atmospheric pollution by winds.
A final important consideration that emerges from the data on emissions is that, in contrast to customary beliefs, road transport is not the main source of emissions of fine particulate matter, coming in second place after non-industrial combustion, which is characterised mainly by domestic heating plants and, alone, produces over 65% of PM_{10} and almost 70% of $PM_{2.5}$ in terms of regional emissions.

Tab. 13.2.2 - Fattori di emissione INEMAR per le attività SNAP della combustione domestica di legna (grammi per gigajoule - g/Gj) - Anno 2010

	PM_{10} (g/Gj)
Caminetto aperto	860
Stufa tradizionale	480
Caminetto chiuso	380
Stufa o caldaia innovativa (stufa moderna, stufa maiolica e caldaia innovativa)	380
Caldaia con potenza termica < 50 MW	380
Stufa automatica pellet/cippato	76

Fonte: Elaborazioni Regione Veneto - Sezione Sistema Statistico Regionale su dati INEMAR Veneto 2010