More electric mobility: future scenarios and air quality in Italian cities

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Executive summary

The impact on the environment and on health of air pollution in recent years is at the center of attention not only by the scientific community, but also by local administrations, governments and citizens.

Transport is one of the sectors responsible for the emission of pollutants in a significant percentage in the urban environment.

The main pollutants of interest are atmospheric particulate matter (PM10 and $PM_{2,5}$) and nitrogen dioxide (NO_2) clearly associated with health effects such as the increase in cardio-respiratory symptoms, the increase in chronic cardiorespiratory diseases, increased mortality and reduced life expectancy.
Recently the European Environment Agency (EEA - Air quality in Europe, 2020 report) found that, in 2018, fine particulate matter ($PM_{2,5}$) caused approximately 417,000 premature deaths among citizens of the European Union. NO_2 caused about 55,000 and O3 20,600 per year.

The CNR - Institute on Atmospheric Pollution in collaboration with MOTUS-E, the association for the development of electric mobility in Italy, has conducted a study for the evaluation of the dispersion into the atmosphere and the impact on the ground of primary and secondary pollutants and the relative emission impact in the cities of Turin, Milan, Bologna, Rome and Palermo. The study examines and compares two prospective scenarios, respectively in 2025 and 2030, of the current fleet of vehicles relating variably to the private transport and logistics sectors of the five Italian cities.

From the results obtained it is evident that, within a broader scenario of replacement of the private vehicle fleet, the penetration of a percentage of electric vehicles (4% - private vehicles - and 5% - light commercial vehicles for the scenario to 2025 and 20% - private vehicles - and 15% light commercial vehicles - for the 2030 scenario) play a fundamental role in reducing the concentrations of local pollutants, in particular NO_2 and in any case significant PM_{10}.

Also significant is the reduction in the number of deaths for cities such as Milan, Rome and Turin in relation to the concentrations of NO_2 and PM_{10} and the relative social cost (VSL) associated with the number of deaths avoided, linked to the changes in concentrations of PM_{10} and NO_2 due to the contribution of traffic alone, which occur in the various hypothesized scenarios, and which varies between about 140 million and about 2 billion euros in the 2025 scenario, and about 222 million and 3 billion in the 2030 scenario.

Acknowledgments

The report "***More electric mobility: future scenarios and air quality in Italian cities***" was coordinated by Dino Marcozzi (Motus-E) and Francesco Petracchini (CNR-IIA), in collaboration with Valeria Rizza (CNR-IIA) who supervised the implementation of the electric mobility penetration scenarios, developed in collaboration with Motus-E, for the assessment of the benefits of air quality and health and economic impacts and Laura Tomassetti (CNRIIA), Valentina Cozza (CNR-IIA) , Marco Torre (CNR-IIA) and Patrizio Tratzi (CNR-IIA) who took care of the collection and processing of data on air quality and data on mobility.

Special thanks for the contributions to the text to Cristina Leonardi and Roberta Spinetti (CNR-IIA), Cinzia Perrino (CNR-IIA), Francesco Naso and Matteo Corda (Motus-E).

Thanks for providing the mobility data to ASSTRA, ACI, ISTAT, 5T, the Municipalities of Milan, Bologna, Palermo and Rome.

For the data relating to air quality and climate data, we thank Arpa Emilia Romagna, Arpa Lazio, Arpa Sicilia, Arpa Lombardia, Arpa Piemonte.

Thanks for the collaboration to all the staff of Motus-E and of the CNR-IIA for the realization of this report.

Graphic design, information architecture, infographics and layout: Giorgia Ghergo - Heap Design

Introduction

The CNR – Institute on Atmospheric Pollution in collaboration with MOTUS-E, the association for the development of electric mobility in Italy, has conducted a study for the evaluation of the dispersion into the atmosphere and the fallout on the ground of primary and secondary pollutants and the relative emission impact in the cities of Turin, Milan, Bologna, Rome and Palermo.

According to the latest report from the World Health Organization (WHO) "Ambient Air Pollution: a global assessment of exposure and burden of disease", published in September 2016, air pollution is the main source of environmental risk for the health of the world population, particularly in urban areas that constitute the most populated areas.

The European Environment Agency (EEA – Air quality in Europe, 2020 report) found that, in 2018, fine particulate matter ($PM_{2,5}$) caused approximately 417,000 premature deaths among EU citizens, NO_2 caused about 55,000 and O3 20,600 per year.

According to a study conducted by the University of Utrecht[1], Italian cities hold the record in terms of premature deaths related to air pollution.

The study refers to the number of premature deaths attributable to air pollution that could have been avoided, compared to the two main pollutants examined, fine particulate matter ($PM_{2,5}$) and nitrogen dioxide (NO_2), based on the population. and the mortality rate of each city.

The Italian cities in which NO_2 pollution is greatest are Turin (in third place) and Milan (in fifth).

Another study[2], commissioned by the European Public Health Alliance (EPHA) in 2018, reports Rome, Milan and Turin among the top 25 European cities for absolute social costs related to atmospheric pollution.

Vehicular traffic is the main cause of this pollution almost everywhere, with contributions ranging from 40% to 80% depending on the different geographical contexts[3]. The vehicle fleet is still largely made up of Euro 4 cars or lower categories, while a significant share of new registrations (about 58%) is represented by diesel cars[4].

Motus-E has developed scenarios for the penetration of electric mobility in Italy that may be the basis of the industrial development of the transition for the ecosystem of sustainable mobility. The study aims to quantify the effects deriving from a possible implementation and understand the benefits, not only in environmental terms, but also in health and economic terms, that the development of electric mobility will bring to the climate of our cities.

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1 https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(20)30272-2/fulltext 2

2 https://www.cedelft.eu/en/environmental-economics

3 https://www.isprambiente.gov.it/it/pubblicazioni/stato-dellambiente

4 http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche.html

The study considers scenarios on strictly scientific traffic flow models and weather regimes, using models developed to evaluate the impact of the penetration of electric mobility, naturally considering the main impacting modes of transport, therefore not only motor vehicles, but also freight transport. Light, very important in urban centers for the development it has and will increasingly have in the post-lockdown.

CNR-IIA developed the study using the ADMS (Advanced Dispersion Modeling System) - Roads[5] software, an advanced stationary analytical model for estimating the dispersion of atmospheric pollutants from the simplest case, such as a single point or linear source, to the most complex of the urban reality, based on specific weather data for each city examined, according to the traffic flows relating to each sector of urban mobility analyzed and implementing the scenarios hypothesized by Motus E.

Following the estimation of the concentrations of the pollutants in question, in particular PM_{10} and NO_2, these data were used to estimate, using the BenMap[6] software, developed by the U.S. Environmental Protection Agency (EPA), the benefits in terms of health impact, such as deaths, and economic impact (estimated associated costs) caused by the changes in concentration resulting from the scenarios implemented.

5 http://www.cerc.co.uk/environmental-software/ADMS-Roads-model.html

6 https://www.epa.gov/benmap

The European and national programmatic objectives in the transport sector

Curated by Francesco Naso e Matteo Corda

The primary EU long-term objective is the elimination of CO_2 emissions in the continental perimeter by 2050.To progress towards this objective, the "Fit for 55" package was approved, with the goal to pursue 55% net GHG emissions reduction target for 2030, compared to 1990 values.
"Fit for 55" is the name given to the set of laws on climate change that will accompany member states in reaching the 2030 target. This will entail – by June 2020 – a further tightening of the goals summarized in the following chapter, which will necessarily be revised and translated, especially in case of Regulations respect to Directives, into new binding goals for individual member states and for manufacturing industries.
If the sectors covered by the CO_2eq Emissions Trading (ETS) are subject to a centralized control system at the European level, the sectors which are not in scope (including road transport) are governed by a Commitment Sharing Regulation (Effort Sharing Regulation or Regulation 2018/842).
If, as required, the Effort Sharing Regulation mechanism (currently re-examined) comes into effect for the sectors that are not covered by the emissions trading system (ETS), Italy would be expected to reduce CO_2 emissions by 33% by 2030, compared to 2005 values.

In this context, Italian transports are the leading issuers of CO_2, with the sector being therefore called to give the maximum contribution, which – for the Integrated National Energy and Climate Plan – equals to -46 million tons of CO_2 equivalent.

Anno	**2005**	**2015**	**2020**		**2025**		**2030**	
Settore			**Scenario**		**Scenario**		**Scenario**	
			Base	**PNIEC**	**Base**	**PNIEC**	**Base**	**PNIEC**
Industria (incl. processo e F-gas)	55	42	42	41	39	37	36	34
Civile	87	73	72	72	67	61	65	52
Agricoltura (consumi energetici)	9	8	8	8	7	7	7	7
Trasporti	125	103	100	95	101	92	93	79
Agricoltura (allevamenti coltivazioni)	32	29	31	31	31	31	31	31
Rifiuti	22	19	16	16	14	14	13	13
Totale	330	274	268	263	258	242	245	216
Obiettivo -33% al 2030			291	291	243	243	221	221

Table 1 – Historical trend of emissions in the ETS sectors and future scenarios with current policies and PNIEC (Mt di CO_2eq)
Source: PNIEC-ISPRA

The main responsible for these emission levels is certainly the road transport sector: only cars and vans, in particular, are responsible for 61% of the emissions.

For this reason, emissions targets at the European level have been included in a series of Regulations and Directives that impose binding targets to States and industry:

Regolamento/Direttiva	Target 2025/2030	Destinatario
Standard CO_2 per auto	-15%/-37,5%	Costruttori
Standard CO_2 per furgoni	-15%/-31%	Costruttori
Standard CO_2 per veicoli pesanti	15%/30%	Costruttori
REDII	14%FER nei trasporti al 2030 in Transport in 2030 (di cui 7% obbligatorio da biocarburanti avanzati e elettricità rinnovabile e max 7% opzionale da biocarburanti convenzionali)	Stato Membro su Fornitori di Carburante
Direttiva Veicoli Puliti	45% al 65% di HDV puliti, di cui almeno dal 22,5 % al 32,5% a zero emissioni	PA

Table 2 - TTarget on emissions at European level and Regulations and directives
Source: Mobilitaria 2019

- Regulation 631/2019 on CO_2 Standards has revised the maximum limits of gCO_2 / km that the fleet of cars and vans registered every year by each car manufacturer will be able to issue, on average, within the European perimeter. It is a push to improve the efficiency and the emission profiles of vehicles, which has led manufacturers to produce and sell a growing number of zero-emission vehicles year after year, under penalty of major fines. For cars, therefore, an average limit of $95gCO_2$ / km was imposed in 2020: in reality, this limit must be calculated by each OEM on the basis of the average mass of the new registered vehicles. This limit will have to be further reduced by 15% by 2025 and by 37.5% by 2030. For vans, on the other hand, the reduction compared to the value calculated by each OEM will have to be reduced by 15% and by 31% in 2025 and 2030 respectively. However, there are adjustment mechanisms for both categories, such as a higher count of zero-emission cars in assessing compliance with the objective or the possibility of buying credits from other more virtuous manufacturers to lower one's average gCO_2 / km value (possibility to form pools between different manufacturers).
- Regulation 1242 of 2019 on CO_2 standards for heavy vehicles (buses and trucks): the above has also been set for buses and trucks registered in Europe from 2025 onward. In particular, from that year, there should be

a 15% reduction of the average gCO_2 / km of all vehicles sold by each manufacturer, in order to achieve a reduction of 30% in 2030. The 2030 target will also be further revised in 2022, verifying the state of development of the technologies that can meet these needs. While, on the one hand, the electric solution is already a market reality for buses, issues related to costs, the range of the vehicle and its autonomy still have to be addressed in the long-haul heavy goods transport.

- The RED II directive requires Member States to use 14% of renewable energy sources in the transport sector by 2030, as shown in the graph taken from the National Integrated Energy and Climate Plan below. This limit is reached through a mix of renewable resources (advanced biofuels, biomethane, electricity), each with a multiplying factor that contributes to the calculation of contributions. However, in light of the new challenges on EU's CO_2 reduction, this value (which had already been revised upwards in December 2019 compared to the previous value of 21.7%) is expected to increase until it reaches a target of 28- 30% by 2030. This will obviously make the contribution of electricity from renewable sources even more important as the latter, in road transport, are assigned the highest multiplication factor of 4, which is already now expected to contribute 404 in the PNIEC kTep.

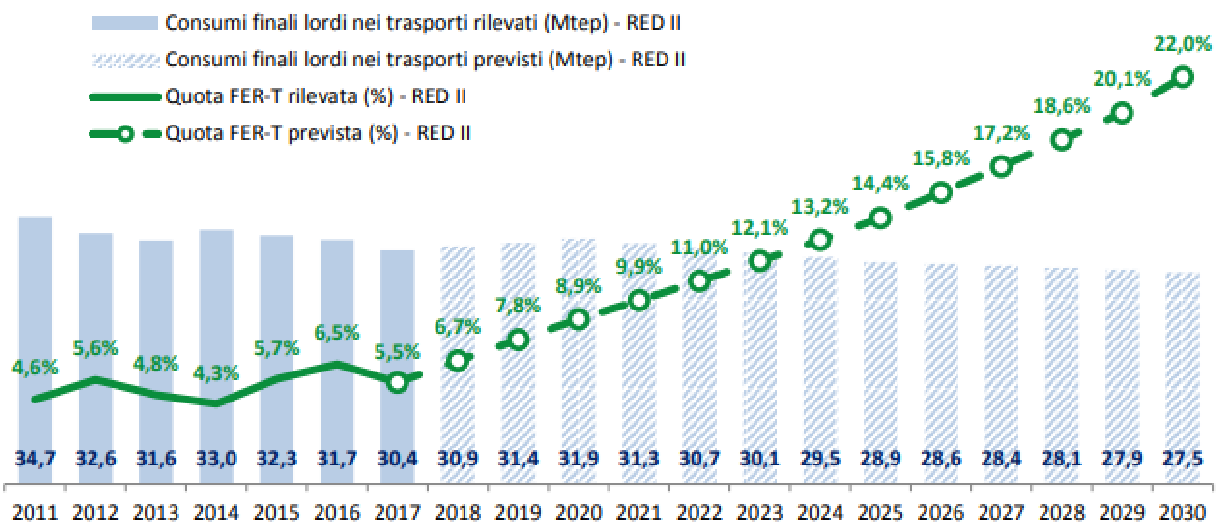

Fig. 1 – Trajectory of the RES share in the transport sector (source GSE and RSE)

- The Clean Vehicle Directive, or Directive 1161/2019, intervenes on the purchase of vehicles by the public administration and requires that public fleets (cars, vans, buses, municipal utility trucks, etc.) have a minimum percentage of low-emission vehicles (45% and 65% of all purchases or rentals made in 2025 and 2030 respectively) and zero-emission vehicles (from 22.5% to 32.5%). The transposition of the Directive on alternative fuels (Law 256/2016) first and the Budget Law of 2020 later, have already somehow implemented some indications, requiring that 50% of the vehicles purchased by the PA are hybrid, electric or hydrogen.

These regulatory contexts, which are constantly changing and involve a close update of the objectives set out in this forum, underpin the national transport objectives for 2030, that have been outlined in the following planning documents, presented by the Government among others:

- The **Integrated National Energy and Climate Plan** (PNIEC), which will have to be further revised in the course of 2021 and provides:
    - 4 million battery electric vehicles and 2 million plug-in hybrids
    - Increase in the modal share of local public transport and sharing
    - 22% of primary energy in transport will have to come from renewable sources

Parametri e variabili generali	Unità	2005	2010	2015	2020	2025	2030	2035	2040
Numero di passeggeri-km	milioni pkm	934,705	959,227	939,935	996,913	1.011,175	1.044,145	1.066,586	1.086,495
Trasporto pubblico su strada	milioni pkm	101,454	109,322	102,605	105,08	107,022	108,901	112,051	112,281
Auto private	milioni pkm	680,000	698,39	676,350	717,501	714,012	724,982	730,551	736,163
Motoveicoli	milioni pkm	49,212	41,480	41,300	40,966	41,442	42,321	44,314	46,401
Trasporto su rotaia	milioni pkm	56,400	54,300	58,900	64,919	73,433	87,268	91,549	96,040
Aerei	milioni pkm	42,655	50,904	55,919	63,446	70,138	75,439	82,748	90,020
Navigazione interna	milioni pkm	4,983	4,831	4,861	5,001	5,127	5,234	5,373	5,590
Numero di tonnellate-km	milioni di tkm	269,484	268,341	218,909	235,774	249,073	262,740	274,132	283,832
Strada	milioni di tkm	192,400	201,593	150,237	160,580	169,946	179,773	187,361	190,715
Rotaia	milioni di tkm	22,761	18,600	20,781	24,506	26,136	27,701	29,112	31,241
Navigazione interna	milioni di tkm	54,323	48,148	47,891	50,687	52,991	55,266	57,659	60,877

Table 3 - Programmatic objectives of the Integrated National Energy and Climate Plan (PNIEC) from 2005 to 2040

- The **National Strategic Plan for Sustainable Mobility** allocates 3.7 billion euros for the replacement / renewal of the bus fleet of local public transportation by road and the improvement of air quality. The declared goal is to bring the average age of the park closer, from current 11.4 years to 7.5 of the European average.
- The **National Infrastructure Plan for Recharging Electricity-Powered Vehicles** (PNire) provides provisions aimed at encouraging the development of sustainable mobility through electric-powered vehicles. Specifically, it provides measures to encourage the creation of recharging infrastructures in order to facilitate and enable the diffusion of public and private fleets of low-emission vehicles. In particular:

  1. Build 4,500 – 13,000 slow/accelerated charging points with public access by 2020
  2. Build 2,000 – 6,000 public access fast charging stations * by 2020
  3. Set up at least 500 motorway petrol stations with public access fast charging stations by 2020
  4. Establish at least 1,750 roadside refueling stations with public access fast charging stations by 2020
  5. Set up at least 1,750 "*traffic attracting poles*" with public access fast charging stations (i.e. shopping malls, supermarkets, large railway stations, amusement parks, interchange parking lots in subway terminus, airports and ports, etc.) by 2020.

The PNIRE is also under review and it is expected to be updated in the first half of 2021, in order to set out objectives for 2030 and intermediate targets for 2025.

*(By fast charging stations we mean sites equipped with fast multi-standard charging systems with a power higher than 40 kW and which are able to guarantee absolute interoperability with all electric and hybrid plug-in vehicles).

The current version of the National Recovery and Resilience Plan (PNRR) was also analyzed as presented to Parliament and Senate in January 2021: at the moment, not only there are no new targets or updates of the existing ones, but there is also no link between the objectives that the Government has proposed on electric mobility and air quality (which we have tried to summarize in this chapter) and the measures described in the Plan.

The European and national regulatory framework on air quality and climate change

Curated by Cristina Leonardi e Roberta Spinetti

In the 90s the European Union started a profound work of reorganization of the legislation governing evaluation activities and air quality management in member countries, with the aim of harmonize the procedures used for the monitoring of pollutants atmospheric conditions and strengthen policies aimed at achieving a general one reduction of the concentrations in the air of substances harmful to health human and for the environment.

Despite the numerous actions taken to improve quality of the air throughout the territory of the Union, the quality standards set by the current legislation, ie Directives 2008/50 / EC and 2004/107 / EC, are still exceeded in large areas of the European territory. And, as is clear from the report 2020 "Air quality in Europe" produced by the European Environment Agency, atmospheric pollution is now one of the established causes of morbidity and mortality among Union citizens; it appears, in fact, that the number of deaths premature attributable to $PM_{2,5}$ particulate matter concentrations in 2018 corresponds to approximately 379,000 while those related to mergers of nitrogen dioxide (NO_2) and ozone (O_3), respectively, at 54,000 and 19,400.

Even in Italy, there are still problems in large areas of the territory in where the limit values and target values set are exceeded by the legislation for the pollutants mentioned. In particular, the situation relating to particulate matter and nitrogen dioxide, so the European Commission has initiated infringement procedures for failure compliance with legislation. The open infringement procedures are as follows:

- n. 2014/2147 for non-compliance with the limit values of the material PM_{10} particulate matter - sentenced;
- n. 2015/2043 for failure to comply with the limit values for nitrogen dioxide (NO_2) – referred to the Court of Justice;
- n. 2020/2299 relating to particulate matter $PM_{2,5}$ – in the initial phase, of formal notice.

With reference to PM_{10}, one was issued in November last year sentence condemning Italy for having repeatedly exceeded the limit values and why, despite having applied reduction measures, the concentrations do not have been reported below air quality standards in the shortest time possible time, as required by law.

The emission trends for these pollutants are decreasing and reduction of concentrations is evident throughout the national territory but such improvement is not yet sufficient to ensure compliance with values limit. To promote an improvement in the situation, the Commission European Union has implemented numerous legislative and non-regulatory actions, including the adoption of directive 2016/2284 / EU (the so-called directive NEC – National Emission Ceilings) concerning the reduction of emissions of certain air pollutants. This directive aims to act on sectors that contribute most to the levels of the most critical pollutants, introducing targets for reducing emissions of the following pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3), compounds non-methane volatile organic compounds (NMVOCs) and $PM_{2,5}$ particulate matter. To each State is assigned a percentage reduction target for emissions 2020 and 2030, compared to the values recorded in 2005. With the objectives set for 2030 is expected to achieve a reduction of about 50% in premature deaths compared to those of 2005.

In parallel, an analysis of the effectiveness of the current legislation on air quality, the so-called "Fitness check", has been carried out, aimed at highlighting the aspects that require an update in view of the forthcoming revision of Directives 2008/50 / EC and 2004/107 / EC. The process was based on the experience accumulated in all Member States in period from 2008 to 2018 and led to the conclusion, among other things, that it will be it is necessary to make air quality standards more ambitious, above all that established for $PM_{2,5}$, and that it will be useful to develop further guidelines for harmonize the procedures followed for monitoring, the use of tools modeling and drafting of air quality plans.

From the ongoing discussions on many international and community tables, moreover, it now seems inevitable that the introduction of provisions relating to other pollutants, which among other things have links also with the theme of climate change, such as methane, black carbon and ultrafine particulate matter.

At the national level, numerous initiatives have been put in place to produce the necessary improvement in air quality, both at the level national and in close coordination with the regional authorities.

In implementation of the NEC directive, implemented in Italy with legislative decree 30 81 of May 2018, a National Control Program was prepared of Atmospheric Pollution, aimed at the adoption of reduction measures useful for achieving the objectives assigned to Italy, shown in the following table.

Pollutant	2020 goals	2030 goals
SO_2	35%	71%
NO_x	40%	65%
COVNM	35%	46%
NH_3	5%	16%
$PM_{2,5}$	10%	40%

Objectives assigned to Italy indicated in the National Control Program

The first program was elaborated and transmitted in its version preliminary to the European Commission by the deadline set for April 1, 2019. Currently the document is undergoing the procedure of Strategic Environmental Assessment, at the end of which it can be adopted officially by decree of the Presidency of the Council of Ministers.

The reduction measures were identified on the basis of an investigation technique carried out by ISPRA and ENEA which was based on the analysis of inventories of national emissions and emission scenarios in 2020 and 2030, in the hypothesis business as usual and the adoption of some reduction policies. From the scenarios to 2020 it appears that the reduction targets will be achieved for all pollutants in the trend scenario while they are indispensable additional reduction measures to achieve the 2030 objectives. The measures identified relate to the sectors that contribute most to the levels national emissions ie the production of electricity, residential and tertiary sector, transport and agriculture, and have been identified in accordance with those included in the National Integrated Energy and Climate Plan, aimed at reduction of greenhouse gas emissions.

Some measures have already been taken while others are currently alone planned and will be implemented in the years to come.

Some of the measures for which resources have already been allocated are particularly related to the transport sector, certainly one of the sectors most responsible for the emissions of some pollutants, mainly nitrogen dioxide in urban areas or in the territories crossed from the main road arteries.

Mobility measures are for example included in the Ministry Agreements of the environment of the protection of the territory and the sea with the Regions of the Basin Padano and in the Clean Air Protocol signed by the President of the Council of Ministers, representatives of eight Ministries and the Conference of Regions on 4 June 2019 in Turin, in the presence of the European Commission.

The planned actions concern the displacement of private mobility of passengers towards collective mobility and smart mobility, of freight transport from road to rail but also vehicle efficiency, promotion of the use of advanced biofuels and other renewable fuels, the strong methanisation of goods transport both by road and by sea as well as a strong push, through fiscal and regulatory measures, in favor of the electric car.

It is also planned to reduce the need for private mobility, thanks to greater diffusion of tools such as smart working, car sharing and car pooling and cycle-pedestrian mobility, with a simultaneous increase of local public transport, including through the implementation of the Plan on sustainable mobility that provides resources for the purchase of electric buses and a methane for the integration and modernization of the existing bus fleet.

The strategies implemented to reduce air pollution are have been identified in line with what was elaborated in parallel in the sector of the fight against climate change. It is now clear, in fact, that only the promotion of synergies between the two sectors could bring significant results for the implementation of new European policies aimed at protection of the environment.

The transport sector, for example, is not only one of the main ones responsible for nitrogen dioxide emissions, it is also responsible for a quarter of CO_2 emissions in Europe. In 2018, in Italy, transport has contributed 24.4% to national greenhouse gas emissions; transport on road is the most important source, accounting for 92.9% of the emissions sector, as well as 22.7% of total national greenhouse gas emissions.

In order to reduce these emissions, as early as 2009, EU legislation set mandatory emission targets for new cars (Regulation (EC) 443/2009) and from 2011, for new light commercial vehicles (Regulation (EU) 510/2011). The objectives that these Regulations envisaged starting from 2015 for passenger cars and from 2017 for vans, were reached already in 2013. On 17 April 2019 was therefore adopted the Regulation (EU) 2019/631 which establishes new ones CO_2 emission standard for passenger cars and commercial vehicles light. The Regulation applies from 1 January 2020 and provides for more ambitious reduction targets starting from 2025 and subsequently from 2030 (shown in the following table).

Vehicles	2025	2030
Passenger cars	15%	37.5%
Van	15%	31%

Emissions reduction targets Regulation (EU) 2019/631

In particular, the Regulation provides for an emission reduction target of CO_2 at a European level equal to 15% starting from 2025 both for cars that for vans, and, from 2030, equal to 37.5% for cars and 31% for vans. The European objectives are divided among the manufacturers to which it is assigned a specific reduction target as a function of the vehicle mass sold on the European territory. The Regulation also provides for an incentive to the introduction on the market of low-zero emission vehicles. The builders that will exceed a specific threshold for placing vehicles on the market low-zero emissions, they will get a bonus on the specific objective.

Furthermore, in 2019, for the first time in the European Union, they were established targets for reducing average emissions from new heavy vehicles (Regulation (EU) 2019/1242). In particular, the Regulation provides for a binding target starting from 2025 equal to 15% reduction compared to specific average of CO_2 emissions relating to the year 2019, and a goal by 30% from 2030, unless otherwise established as part of the planned review in 2022.

Furthermore, road transport falls within the scope of the Regulation (EU) 2018/842 on the binding annual reductions of greenhouse gas emissions by Member States in the period 2021-2030 (so-called "Effort sharing" Regulation). This Regulation breaks down the European target of reducing greenhouse gas emissions by 30% among Member States on the basis of per capita GDP in 2013. For Italy is expected a reduction target by 2030 equal to -33% compared to 2005. The rules it applies not only to the transport sector, but also to the non-industrial sector subject to the ETS Directive, agriculture, waste and the civil sector (buildings). On 11 December 2019, the European Commission presented the Communication on the European Green Deal, a package of measures that includes a reduction ambitious greenhouse gas emissions as well as investment in research and innovation, and measures to promote the efficient use of resources moving to a clean and circular economy, restoring biodiversity and to reduce the pollution. In fact, with the Green Deal, a table initial march of the main European policies and measures needed for achieve the European goal of climate neutrality by 2050 is defined. Furthermore, the 10 December 2020, the European Council revised the current reduction target of greenhouse gas emissions for 2030 equal to 40% compared to 1990 levels, increasing it to "at least 55%". In line with the measures identified by the Green Deal, the presentation by the European Commission of proposals for the revision of climate legislation and energy in order to achieve this goal.

As regards the road transport sector, they will therefore be revised the Regulations on the performance of light and heavy vehicles, the Effort sharing regulation, the directive on renewables, the directive on an infrastructure for alternative fuels and the Regulation on networks trans-European transport sectors, as well as a proposal for standards stricter in terms of polluting emissions into the atmosphere for vehicles with internal combustion engine will be presented.

On 10 December 2020, the Commission presented a Strategy for One sustainable and smart mobility, which sets a roadmap for putting the European transport sector on the right path for a future sustainable and intelligent, identifying 10 main areas and envisaging a action plan. The scenarios developed for the definition of the Strategy, online with climate objectives, show that an adequate level of ambition and the combination of measures and policies identified by the Strategy,would allow to achieve a 90% reduction of the transport sector by 2050. The Strategy also identifies a series steps towards achieving the goals of sustainable mobility, smart and resilient. In particular, by 2030, inter alia, the circulation of 30 million zero-emission vehicles on European roads; the doubling of high-speed rail traffic; wide implementation road to automated mobility. Furthermore, it is expected that, by 2050, almost all cars, vans, buses and new heavy-duty vehicles are carbon emissions zero, as well as the doubling of rail freight traffic and rail traffic at high speed has tripled. National policies implemented for the purpose of health protection human beings from possible damage caused by atmospheric pollutants and gases climate-changing are, therefore, in line with the European strategies of the sector and are were also referred to in the preliminary version of the National Plan of Recovery and Resilience (PNRR) #Next Generation Italia.

The ecological transition will be the basis of the new economic and social model development on a global scale and has been identified as a priority by the Plan national. A considerable share of the available resources will be used to favor this process, first of all by intervening on the production and the distribution of energy, favoring the use of renewable sources and realizing the infrastructural interventions necessary for the decarbonisation of the transport.

The effects of urban mobility on quality of the air in Italy

Curated by Cinzia Perrino e Laura Tomassetti

The pandemic due to COVID-19 has caused devastating effects in the health sector and has also had important repercussions in the socio-economic and environmental. The particular living conditions that the fight against the virus has imposed to the population for a few months, never experienced before, have had interesting implications from many points of view. Among these, it is to be considered especially mobility, which has been drastically reduced by the measures imposed to counter the spread of the virus, especially during the months of March and April 2020. These measures involved the population in one sort of collective experiment, which allowed us to show what they are the consequences and influence of human activities, and in particular of mobility, the state of the environment and the quality of the air.

The objective of this chapter is to analyze some air quality data in four sample cities (Turin, Milan, Rome and Naples) to evaluate the local impacts due to the reduction of displacements during lock-down. In addition to verifying the general improvement in air quality, it means quantify the decrease in individual pollutants linked to emissions from vehicular traffic.

Several studies, carried out in various areas of the world, have reported observations on the impacts that the blocking of activities has produced on air quality, on the changes that have occurred since the pre-lock-down period compared to the same months of previous annuities. These observations reveal that the lock-down caused a drastic drop in pollution in most of the areas examined, both as regards the gaseous pollutants and particulate matter suspended in the atmosphere (PM). For example, as indicated by Baldasano et al. (2020)[1], in ten major cities, Delhi, London, Los Angeles, Milan, Mumbai, New York, Rome, São Paulo, Seoul and Wuhan, NO_2 concentration values were recorded between -9% and -60% compared to 2019 data, and between + 2% and -55% compared to the average of previous four years.

Italy is among the first of the many countries that have used lock-down such as tool for reducing the spread of infection. The first confirmed case of Covid infection on the Italian territory was registered on February 20, 2020 in Codogno (Lodi). Starting the next day, the Italian government adopted the first restriction measures, which limited movements, gatherings and other activities in some restricted areas of Lombardy and Veneto. From 4 to 8 March further measures were taken on the national territory, which they have led to a limitation of travel for 16 million people, approximately a quarter of the entire Italian population. Therefore, starting from 11 March it was arranged for the closure of all commercial and restaurant activities, and from 22 March the closure of all non-essential activities, as well as the prohibition of displacement with the exclusion of only work, health or urgency reasons.

1 Baldasano, J. M. (2020). COVID-19 lock-down effects on air quality by NO_2 in the cities of Barcelona and Madrid (Spain). Science of the Total Environment, 741, 140353

All of these measures resulted in a progressive decrease of the sources of traffic pollution throughout the country in consequence of the reduction of the movements of citizens in urban centers, as demonstrated by the statistics developed by Enel X in partnership with HERE Technologies[2]. The graphs shown in Figure 1 show the changes in movements, expressed as a% increase / decrease in total flow of municipal mobility; the variation is calculated with respect to a standard reference period (weighted average for the days of the week of flows recorded in the period 13 January - 16 February 2020). The variations percentages of movements during the lock-down period show a certain variability, especially between midweek periods and holidays and pre-holidays, but they are nevertheless always 50% higher than the period of reference, with values that even exceed 94%.

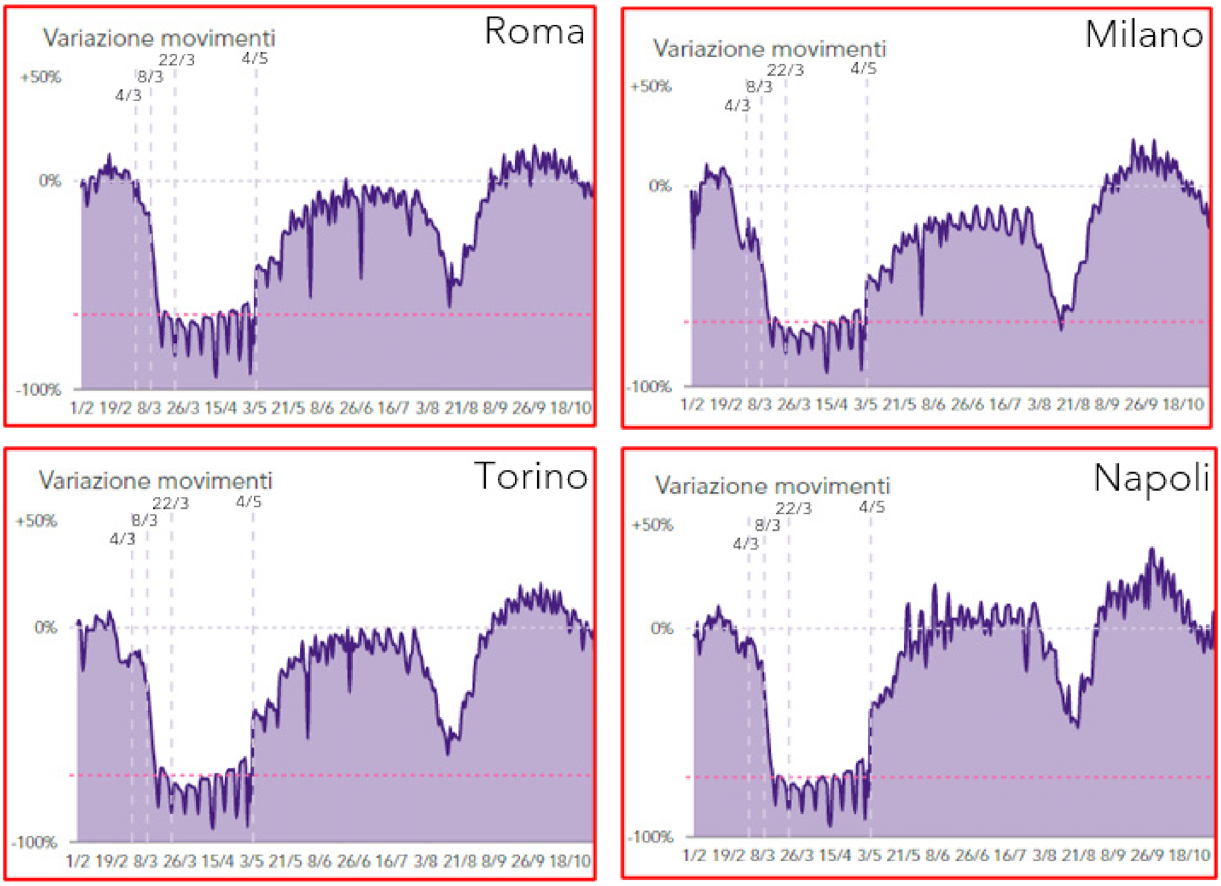

Figure 1 - Change in movements, expressed as a percentage with respect to the period of reference, for the cities of Rome, Milan, Turin and Naples (mobility maps taken from ENEL X1 portal).

Since, as is known, the quality of the air is affected both by the intensity of the sources emissions and dilution capacities of the atmosphere, determined by the weather-climatic situation, both of these factors must be taken into account consideration when you want to evaluate the trend of concentrations of pollutants.

From the point of view of meteorological parameters, the period of the lock-down does not have showed particular singularities compared to the same months of the years 2016-2019. During the month of March the only significant

2 https://enelx-mobilityflowanalysis.here.com/dashboard/ITA/index.html#41.2928!12.5735!6!2020-11-25 (ultimo accesso 05/02/2021)

changes were consistent in a lower global radiation value in the cities of Milan and Turin, and superior in the city of Rome. In addition, more rainfall was recorded copious in Milan, and below the verage of the four previous years in Rome and Turin. During the month of April, in all the cities examined it was observed a higher global radiation value than the reference period, less rainfall, with the exception of the city of Turin, and less humidity relative percentage in Milan and Rome.

More relevant, from the point of view of air quality, are two events, recorded during the month of March, which involved the four in varying degrees cities examined. The first is a period of intense atmospheric stability, which occurred between 17 and 19 March, which involved the whole of Northern Italy. The stability conditions limit the mixing of the air masses and are therefore responsible for the accumulation of pollutants, in particular those of secondary education (not directly emitted from sources but produced by reaction in the atmosphere starting from precursors). Subsequently, from 26 as of March 31, the weather conditions in the country were affected by one cyclonic depression, centered in the Mediterranean, which attracted masses of air from Eastern Europe. In this circumstance, a mass was recorded transportation of sand from deserts from the Caucasian region, which determined an increase in the concentration of atmospheric dust throughout the Center-North. It should be emphasized that episodes of atmospheric stability, albeit less intense than that of 17-19 / 3, they also occurred in other periods in all four cities considered. In particular, they are to be reported for the city of Rome two episodes of medium intensity which occurred in the periods 17 – 22 March and 7 - 13 April.

In order to analyze the air quality data and evaluate the reduction of individuals pollutants in urban areas, the data provided by the Agencies were considered ARPA[3] relating to the period 1 January-30 April 2020 of the four cities taken in examination. The data were compared with those relating to the same period in four previous years (2016-2019). The parameters taken into consideration are the nitrogen dioxide (NO_2) and particulate matter with an aerodynamic diameter smaller than 10 micrometers (PM_{10}). The data refer to all the stations cataloged as "Traffic monitoring station".

For a more effective evaluation of the results, it is useful to compare the data of concentration with the limits imposed by Italian and European legislation. Such limits are equal to 40 μg/m^3, as an annual average concentration, both for NO_2 (protection of human health) and for PM_{10}. For this last parameter, a limit for the average daily concentration was also identified, which can exceed the value of 50 μg/m^3 no more than 35 times per calendar year.

3 Air Quality Data - ARPA Piedmont, ARPA Lombardy, ARPA Lazio, ARPA Campania

NO_2 concentration and PM_{10}

Turin

For the city of Turin there are still critical issues in compliance with the limits of law for both NO_2 than for PM_{10}, despite the values in the last two years of concentration have significantly reduced with respect to annuities previous. By processing mobility data during the period of lock-down[4], it can be observed how in this city the number of movements daily compared to the reference period 13/1 - 16/2 has been reduced by a minimum of 61% up to a maximum of 93%.

For NO_2, during the lock-down there is a clear change in average concentrations recorded in traffic stations during the months of March and especially April 2020, compared to what was recorded in the annuities previous (2016-2019)[5]. In particular, the average concentration of the month of March for the years 2016-2019 stands at 69 µg/m³, while in the same period of 2020 the value was equal to 39 µg/m³. There was a similar difference found for the month of April 2020, when 28 µg/m³ were recorded compared to 57 µg/m³ of previous years. The reduction of concentration, 43% in March and 51% in April was therefore significant.

More in detail, the trend of average daily concentrations (Figure 2) shows that these were not only significantly lower than the average relating to the 2016-2019 period, but also to the interval identified by the standard deviation; the reduction became particularly pronounced after March 22, the day when the total lock-down began.

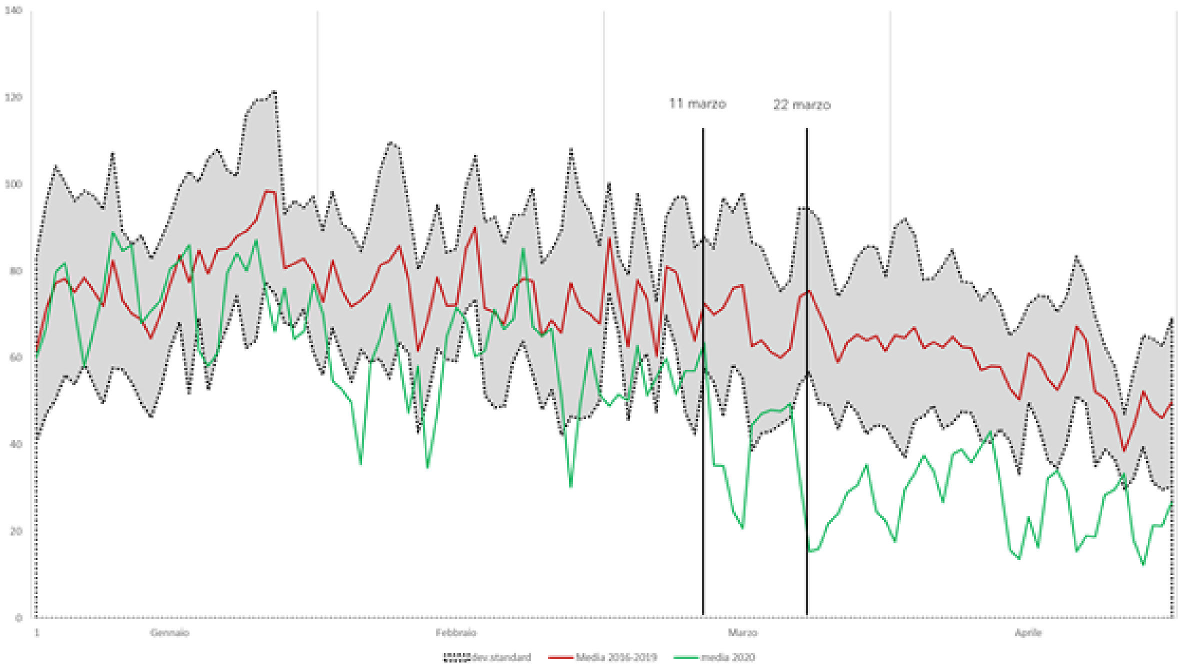

Figure 2 – Turin: Trend of the average daily NO_2 concentration in 2020 and comparison with the period 2016-2019 (traffic stations). The red line indicates the mean of the period 2016-2019; the gray area indicates the standard deviation of the measurements.

4 https://enelx-mobilityflowanalysis.here.com/dashboard/ITA/index.html#41.2928!12.5735!6!

5 http://www.arpa.piemonte.it/news/la-qualita-dell2019aria-a-torino-durante-l2019emergenza-coronavirus

As for the concentrations of PM_{10}, they are not observed instead evident reductions, indeed, during the months of March and April the monthly averages were higher than in previous years. The graph in Figure 3, relating to the comparison between the daily trend of concentrations in 2020 compared to the period 2016-2019, shows that the decrease during the period of the lock-down was very modest, too if we observe, starting from the national lock-down, a general trend towards decrease compared to the average of the reference period. This trend is interrupted by two events that can be linked to the aforementioned phenomena of atmospheric stability, in the period between 17 and 19 March, and transport of dust from the Caucasian regions, on the days of 28 and 29 March (as also indicated by ARPA Piemonte[6]). The weight of these events has significantly affected seasonal mean concentrations.

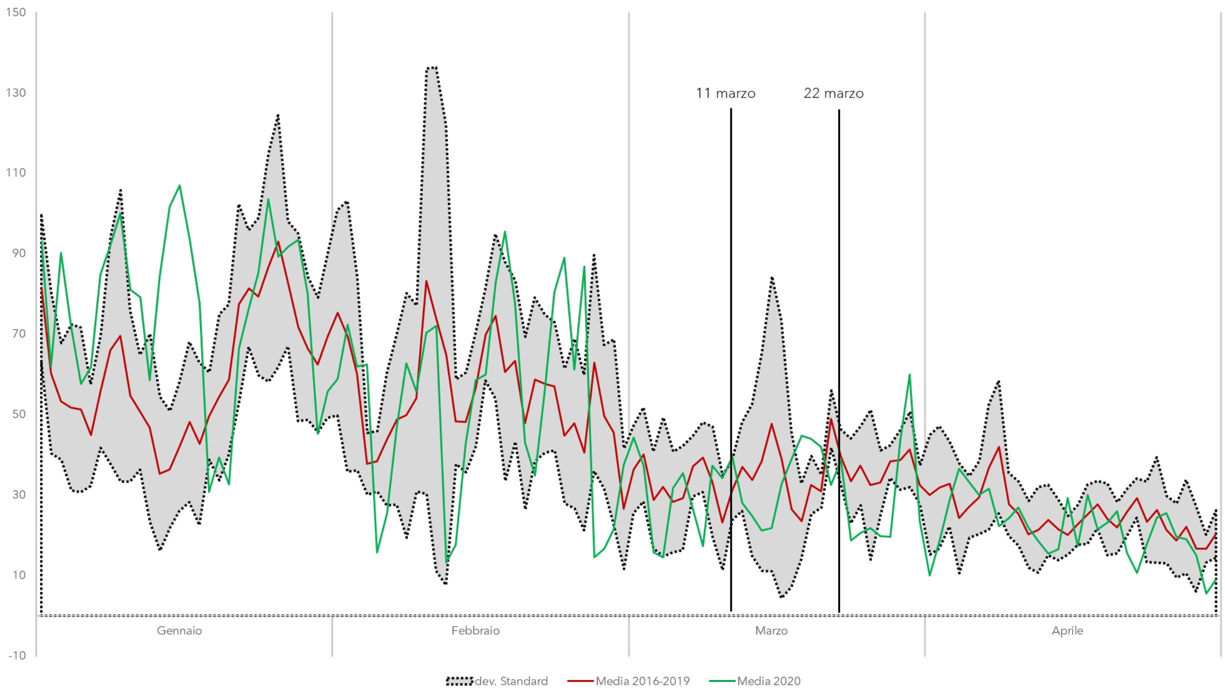

Figure 3 - Turin: Trend of the average daily concentration of PM_{10} in 2020 and comparison with the 2016-2019 period (traffic stations).

6 http://www.arpa.piemonte.it/news/la-qualita-dell2019aria-in-piemonte-durante-l2019emergenza-coronaviru

Milan

The city of Milan typically has annual average concentrations of NO_2 above the regulatory limit of 40 µg/m^3, especially for stations of traffic; as regards PM_{10}, on the other hand, the annual average concentrations are below the legal limits but with a number of exceedances always above the limit of 35 days per year, albeit with a downward trend. During the lock-down, the movements in the city of Milan suffered a drastic reduction compared to the reference period (13 / 1-16 / 2), reaching a daily percentage reduction between 62 and 93%. The data collected in March and April 2020, show that the average monthly concentrations of NO_2 in traffic stations have also decreased significantly: they are found to be lower than 30 µg/m^3 in March (2016-2019 average: 41 µg/m^3) is less than 20 µg /m^3 in April (2016-2019 average: 31 µg/m^3), with a reduction of 29% and 43% respectively.

In this regard, ARPA Lombardia in the report "*Preliminary analysis of air quality in Lombardy during the COVID-19 emergency" observes: "The analysis of air quality data shows that the measures implemented to deal with the emergency have certainly led to a reduction in emissions deriving in particular from vehicular traffic, which are more evident by analyzing the concentrations of pollutants directly linked to traffic, i.e. NO, benzene and partly NO_2, settling around the minimum values or lower than the lowest values recorded on each calendar day in the observation period* ".

Daily data of NO_2 concentrations in traffic stations during the January-April period, shown in Figure 4, clearly show that there were no significant deviations in the January-February period compared to previous years, while during the lock-down period There have been several cases in which the values have been significantly lower to the average of the comparison period and, sometimes, even below the range identified by standard deviation. In most cases, the data they were also below the legal limit of 40 µg/m^3, relating to annual average concentration.

As for the average monthly concentrations of PM_{10}, during the months of lock-down reductions were not particularly noticeable, although the mean concentrations were among the lowest in the last 5 years. To this By the way, Arpa Lombardia reports: "*The reduction observed for particulate matter is significantly influenced in the Po Valley by the presence of the abutment. Under certain conditions, such as those occurring between 18 and 20 March, the trends recorded were in any case influenced by the persistence of some sources and by atmospheric conditions. The observation that drastic reductions of some sources do not always prevent exceeding the limits, while helping to reduce their extent, clearly shows the complexity of the phenomena related to the formation and accumulation of atmospheric particulate and the consequent difficulty of reducing in a drastic way the values present in the atmosphere in ordinary situations* ".

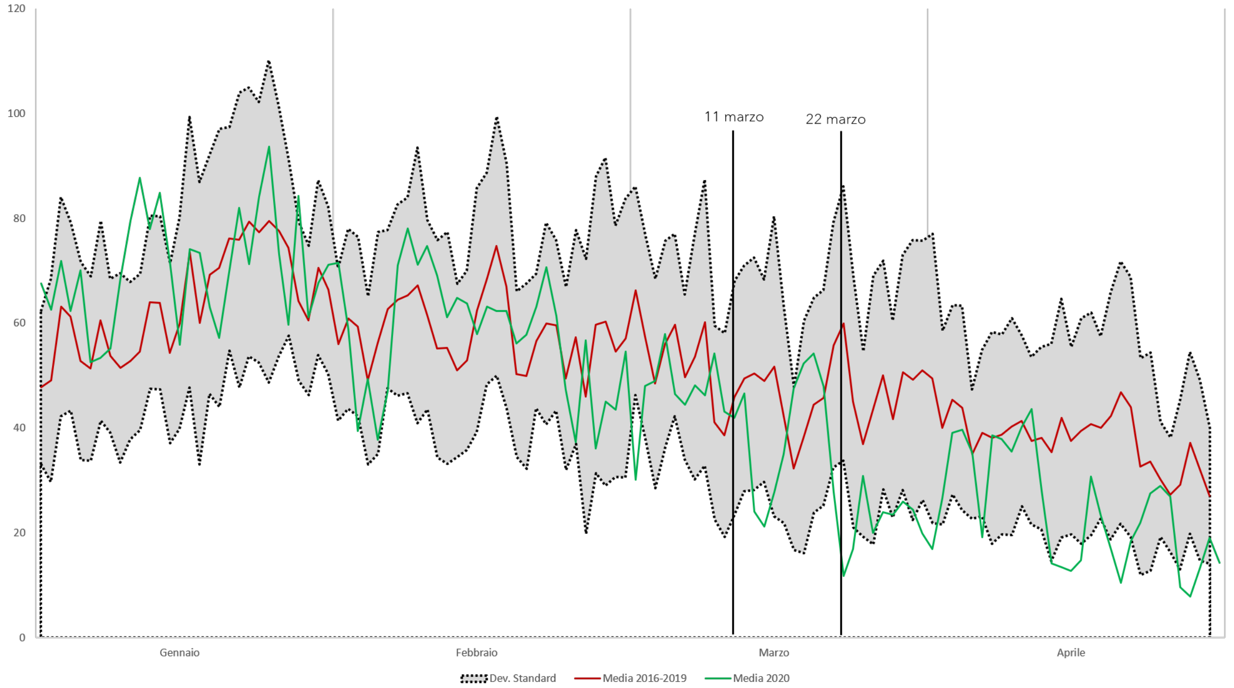

Figure 4 – Milan: Trend of the average daily NO_2 concentration in 2020 and comparison with the 2016-2019 period (traffic monitoring station.).

From the examination of the trend of the daily averages of the concentration of PM_{10} (Figure 5) it can be seen that the 2020 values were slightly lower than in previous years, even if, in general, falling within of the interval defined by the standard deviation. The exceptions to this are days in which the extraordinary events already described for the city took place of Turin (17-19 and 28-29 March).

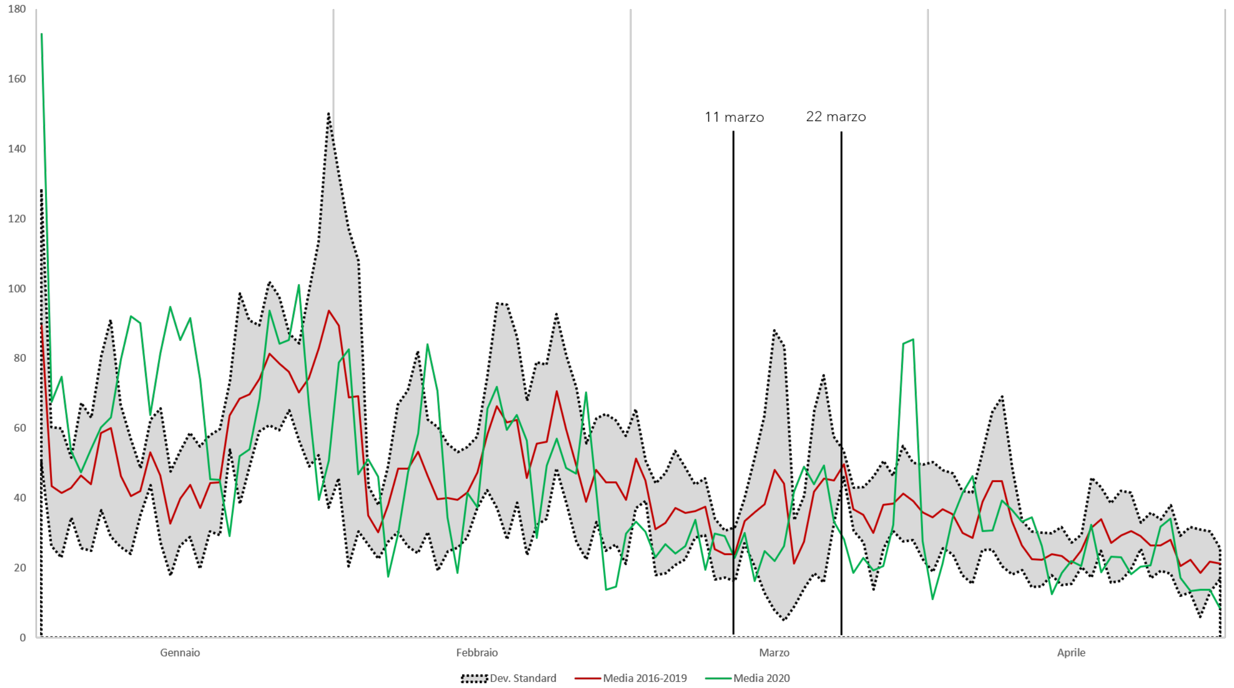

Figure 5 – Trend of the average daily PM_{10} concentration in 2020 and comparison with the 2016-2019 period (traffic monitoring station.).

Rome

Unlike the cities of Turin and Milan, Rome has a geographical location which allows you to have weather and climate conditions and an orography more favorable to the mixing of air masses. Nonetheless, the large volume of traffic in the capital causes problems to remain relating to compliance with regulatory limits for NO_2. As for PM_{10}, the annual average concentration has already returned below the legal limits since 2008, while the permitted number of merger exceedances has been respected since 2017.

Even in the case of the city of Rome, during the period of the lock-down it was recorded a significant decrease in movements, which, on a daily basis, it fluctuated between 70% and 93%. Consequently, in the two months of March-April, yes a marked reduction in monthly mean NO_2 concentrations is observed, which, compared to the 2016-2019 period, underwent a decrease of 59% in March and 71% in April. The daily trend of concentrations in traffic stations, shown in Figure 6, in fact shows, already starting from the first days of March 2020, a reduction in concentrations consistently below both the average for the 2016-2019 period and of the interval defined by the standard deviation.

In this regard, Arpa Lazio in the report "The effect on air quality in Lazio of the COVID-19 emergency. Preliminary analysis of the March data ", observes: "*Taking into account the above, the analysis of the data shows that the lock-down has led to a significant reduction in emissions related to the transport sector, which is clearly the result of the decrease in the concentrations of pollutants directly linked to traffic (nitrogen monoxide, benzene and partly nitrogen dioxide)*".

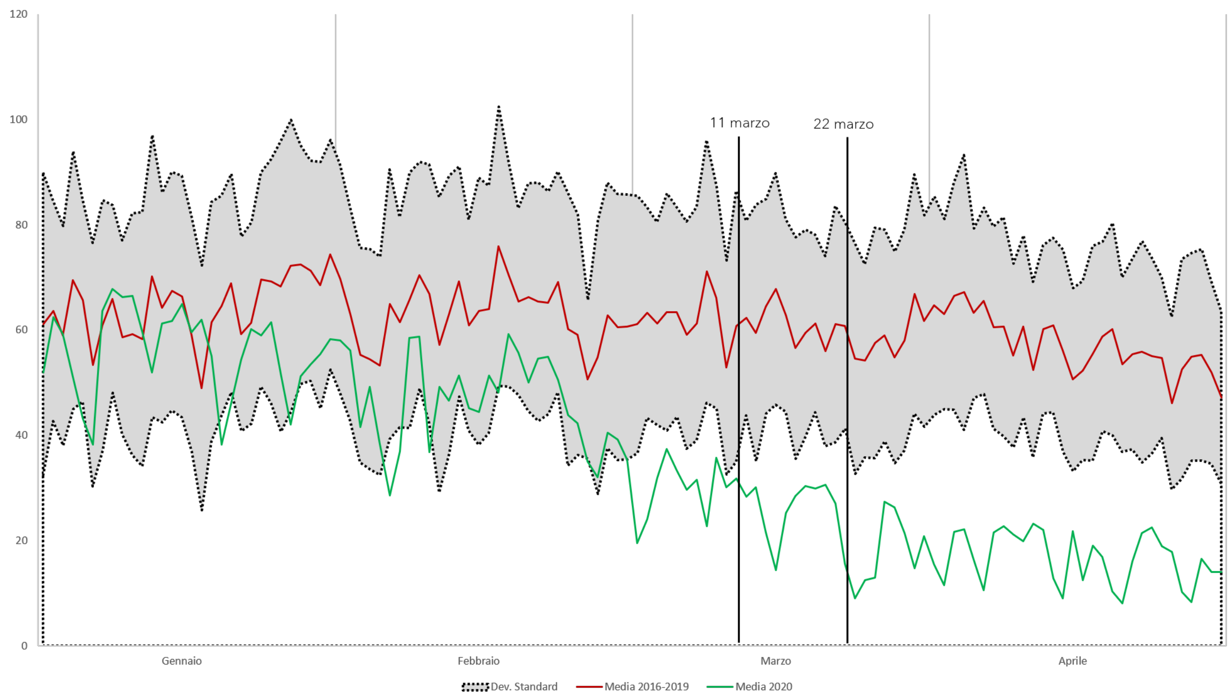

Figure 6 – Rome: Trend of the average daily NO_2 concentration in 2020 and comparison with the 2016-2019 period (traffic monitoring station.).

As regards PM_{10} concentrations, the data recorded in Rome in periods of March and April show two different results. During the month in March the concentration of PM_{10} did not differ much from the average of the period of previous years, while for the month of April it was observed a fair reduction, equal to 27%. The daily concentrations relative to the period under examination, shown in Figure 7, show considerable fluctuations, which sometimes determine values that are clearly lower than the average for the period 2016-2019, and sometimes overlapping.

The almost negligible reductions recorded in the first of the two months taken in examination are due both to the relative weight of the first decade, in which mobility it was still high, both due to the episode of atmospheric stability that occurred in period 17-22 / 3, both at the transport event of desert sands, and in Rome occurred on days 29 and 30 (one day away from the North Italy). In April, however, the only critical period was stability atmospheric from 7th to 13th day, while in the rest of the month the reduction compared at the reference period it appears more marked, also thanks to the shutdown of domestic heating.

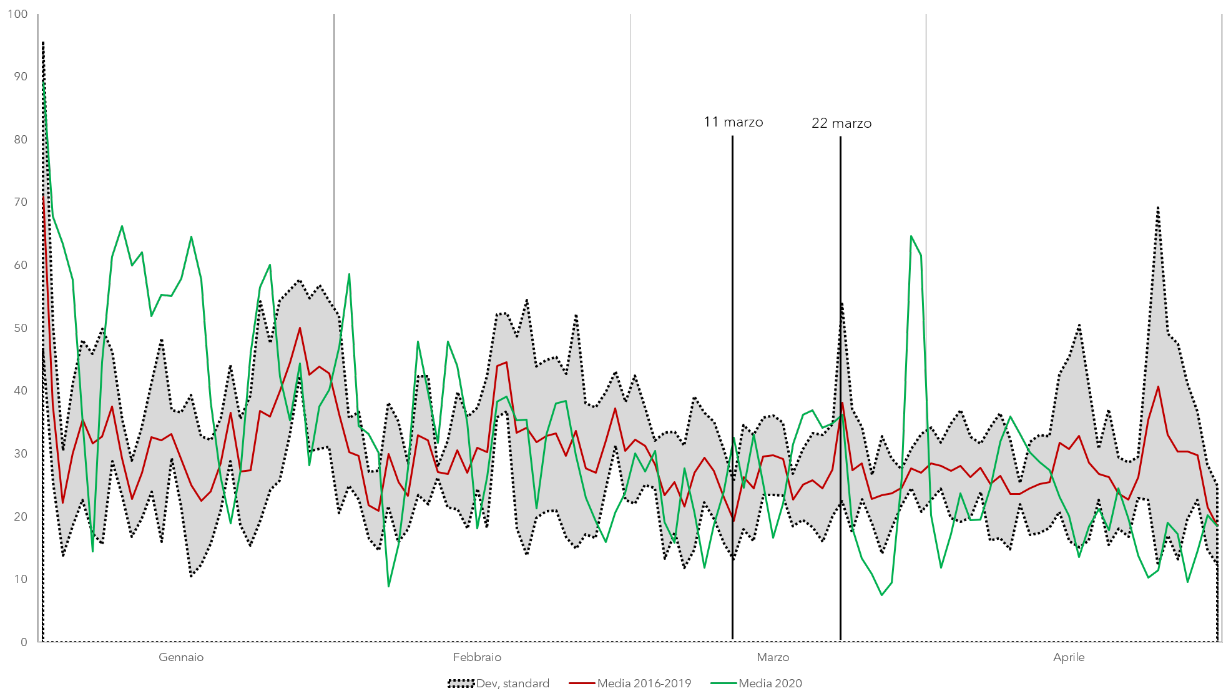

Figure 7 - Rome: Trend of the average daily PM_{10} concentration in 2020 and comparison with the 2016-2019 period (traffic monitoring station.).

Naples

Despite the favorable meteorological conditions determined by the its status as a coastal city, in recent years Naples has recorded, in traffic stations, annual average concentrations of NO_2 higher than regulatory limits; the number of exceedances was also higher than the limits of the average daily concentration of PM_{10}, while the limit for the annual average concentration was respected.

During the period of the lock-down, the reduction in vehicular traffic was remarkable, with a decrease in daily movements between 62% and 95% compared to the period 13 / 1-16 / 2. As a result of this reduction, the NO_2 concentration in traffic stations it decreased by 33% in the month in March and 57% in April. This observation is confirmed by what was reported by the Campania Arpa in document "The measures for the containment of the contagion from Covid-19 and air quality in Campania "*The drop is evident in nitrogen monoxide concentrations. The deviation detected with respect to the modeling estimates can only depend on the reduction of traffic emissions: the Campania Region estimates that in March, on average, 65% of total emissions of nitrogen oxides comes from road transport*".

The trend of the average daily concentrations of NO_2, shown in Figure 8, shows values much lower than the 2016-2019 average, which, starting from the date of the generalized lock-down for all of Italy, they fall into much of it even below the range defined by the standard deviation.

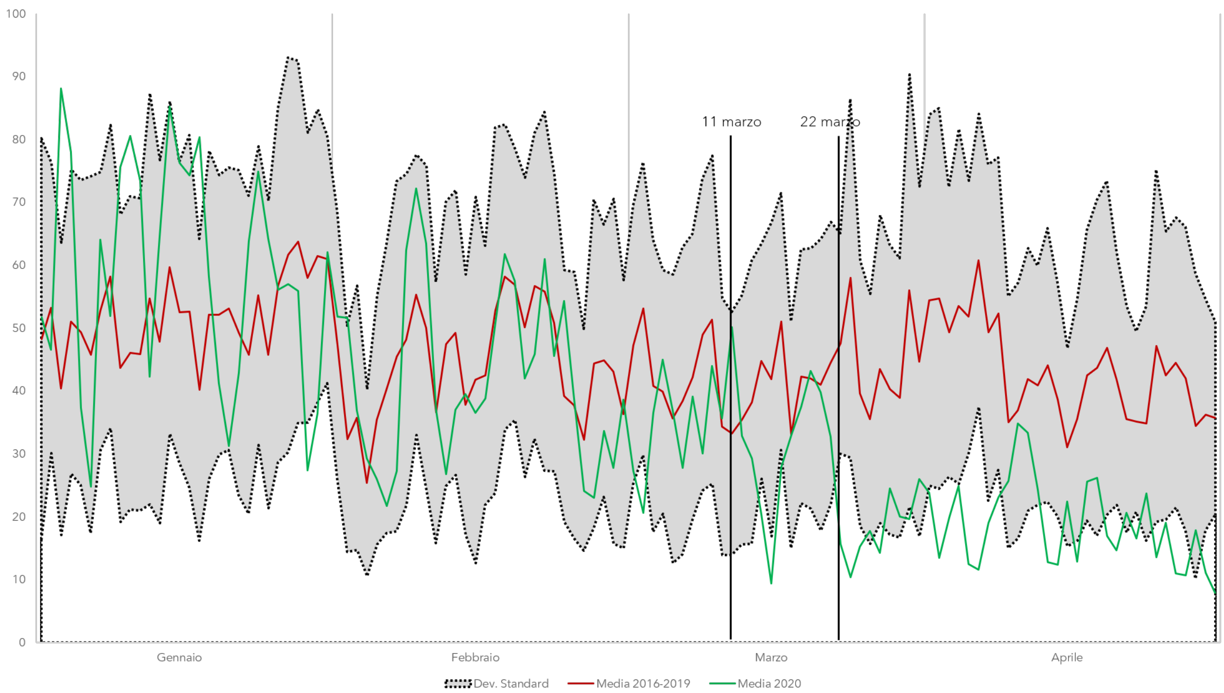

Figure 8 – Naples: Trend of the average daily NO_2 concentration in 2020 and comparison with the 2016-2019 period (traffic monitoring station.).

As in the case of Rome, for PM_{10}, a behavior was found different in the months of March and April. No changes are observed in the first month compared to the concentrations of the previous 4 years, while for April 2020, the average value, equal to 23 μg/m³ , is significantly lower (by 23%) compared to the 2016-2019 average (30 μg/m³).

Regarding the month of March, these observations are confirmed in the Arpa Campania report, which reports: "*Different speech for fine dust PM_{10} and $PM_{2,5}$: in this case the reduction between the expected value and the actual value is smaller. Estimates from the Region indicate that in Campania, on average, in the month of March the heating, as regards PM_{10}, provide over 80% of the emission contributions. This source of emissions has not been blocked at all by the containment measures, on the contrary, due to the rigid temperatures recorded in some periods of March and due to the longer stay of people in the home, the emissions from heating have probably increased compared to the average historical* ".

Also the analysis of the trend of the average daily concentrations of PM_{10} to traffic monitoring stations (Figure 9) showed a reduction compared to average of the period 2016-2019 more evident in April, despite the presence some concentration peaks probably due to episodes of stability atmospheric.

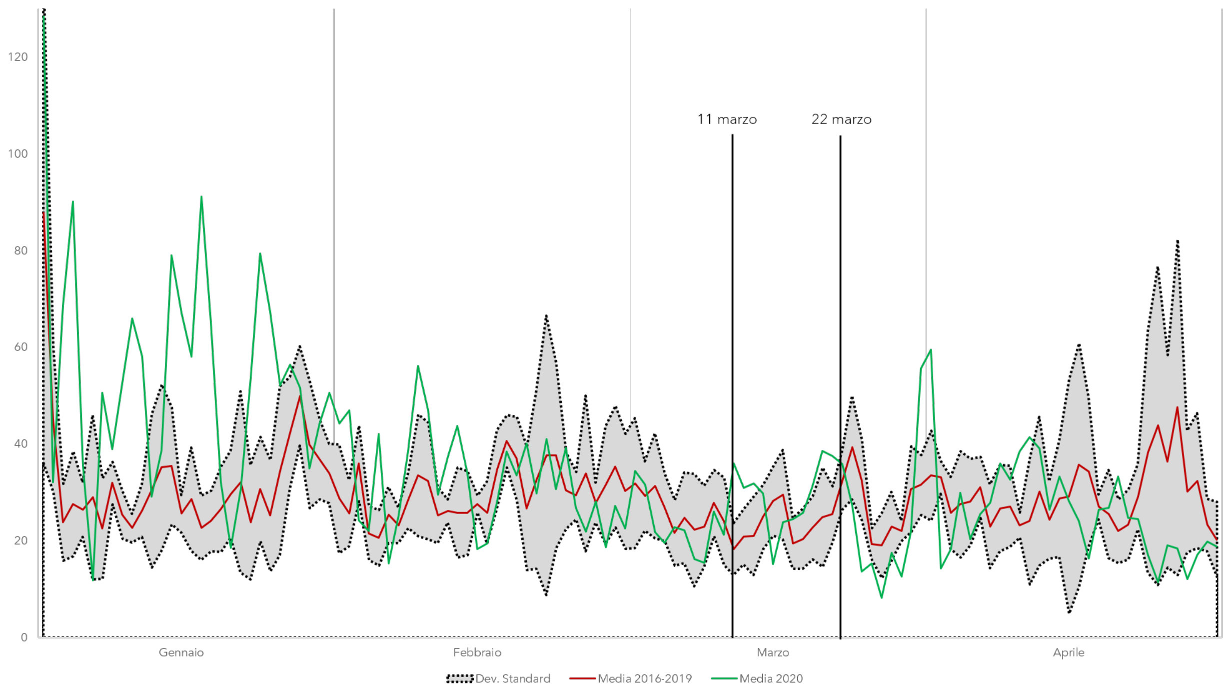

Figure 9 – Naples: Trend of the average daily PM_{10} concentration in 2020 and comparison with the 2016-2019 period (traffic monitoring station.).

Particulate chemistry atmospheric considerations

Unlike gaseous pollutants, such as for example NO_2, for the which the extent of the concentration is generally sufficient to define and interpret their trend, the atmospheric particulate is a class of pollutants of particular complexity. Particles can differ from each other, among other things, by chemical composition, size, shape, density, charge electrical, hygroscopicity, chemical phase (solid, liquid or mixed), sources and effects on human health and the ecosystem. For this reason the measure mass concentration alone is a very coarse parameter, and the understanding of its variations over time must necessarily pass for the knowledge of at least some of these parameters, first of all the chemical composition.

Once the main chemical species that make up the PM have been determined, it also becomes possible to identify the sources from which the particulate matter comes product. The main sources, which are present in any environment urban area of our country, are the soil, the sea, combustion (traffic and heating), the biosphere and secondary formation in the atmosphere (reactions which produce both organic and inorganic species) to which it can be added, in some areas, an industrial spring. It is therefore clear that the reduction mobility, which affects only some of these sources, can only cause a moderate lowering of the mass concentration of PM.

Typically, in a traffic station the direct vehicle emissions ("exhaust") they can contribute 20-30% to the concentration of PM_{10} [7]. THowever, the emissions from the muffler do not exhaust the ways in which the traffic vehicular contributes to the PM. A second important contribution is that due to so-called "non-exhaust" emissions, due to brake abrasion, asphalt and tires and the uplift caused by the transit of vehicles, of the dust deposited on the ground. The revival mainly concerns the dust of crustal origin (source "soil") but, to a lesser extent, involves all particles, of any origin, already present on the ground. It is important to note that the non-exhaust contributions are not related to the fuel used, and that vehicles with electric power also contribute to the release of these particles. The dust produced by "non-exhaust" emissions, as opposed to those generated by combustion are in the plus dimensional fraction large (generally referred to as "coarse", which includes particles with an aerodynamic diameter between 2.5 and 10 µm). For this reason, the weight of this contribution significantly decreases moving away, too a few tens of meters from the source. A third contribution of traffic to the PM concentration is linked to the emission of nitrogen oxides. These species in the gaseous phase constitute in fact the first link in a chain of chemical reactions leading to the formation of nitric acid and therefore, for further reaction with ammonia, to the production of ammonium nitrate in the particle phase (pollutant of a secondary nature, formed in the atmosphere a starting from precursors). The set of directly emitted particles, those abraded and raised and those produced by the secondary route starting from nitrogen oxides can bring the contribution of traffic, measured near the roads, to touch 50% [8].

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7 Processing based on experimental measurements carried out by the Institute on Atmospheric Pollution

8 Processing based on experimental measurements carried out by the Institute on Atmospheric Pollution

The graph shown in Figure 10 shows PM composition data where the different chemical species that make up the particulate matter have been grouped as follows: species released from the soil, marine aerosol, species organic, inorganic species of secondary formation (nitrate, sulphate and ammonium chloride), combustion emissions. It can be seen how the difference in concentration between a traffic station and a background station urban, i.e. not directly affected by road emissions, resides especially in emissions from combustion processes and, to a lesser extent, in the soil component, which includes a significant due fraction to the lifting. The organic fraction, that due to marine aerosol and the secondary one remain substantially unchanged.

For the latter group, it should be taken into account that the secondary species, due to their particular way of formation, they are present exclusively in the fine fraction of the PM, and can therefore also reach areas very far from the point of formation, continuing to generate during the aging process of air masses. Secondary pollutants, therefore they have a much lower spatial gradient than the species directly issued and are distributed evenly over a very area greater than that town. In other words, while stable species (i.e. which do not undergo transformations once emitted into the atmosphere) and those present in the coarse fraction of the powders show a decrease of concentration as you move away from the emission point, the secondary species also form at a considerable distance, generating a more or less constant concentration over an extended area. These species are also particularly sensitive to atmospheric stability conditions, which allow you to continue and intensify the training process. For this reason, in the area of the Po Valley, where the emission of precursors of secondary pollutants is very intense (ammonia production from livestock breeding and agricultural practices) and where frequent stability atmospheric conditions increase the possibility of reaction, the concentration of nitrate ammonium is always very high and substantially distributed homogeneous over a territory that exceeds the regional dimension.

Finally, the comparison with a semi-rural station, located about 30 kilometers away from the center of Rome and about 50 kilometers from the coast (third column in Figure 10)[9] shows a further decrease in combustion emissions and a decrease in the contribution related to marine aerosol. Finally, it should be emphasized that the component linked to combustion processes also contains a very important seasonal contribution, due to domestic heating and in particular the one that uses wood as fuel.

9 Processing based on experimental measurements carried out by the Institute on Atmospheric Pollution

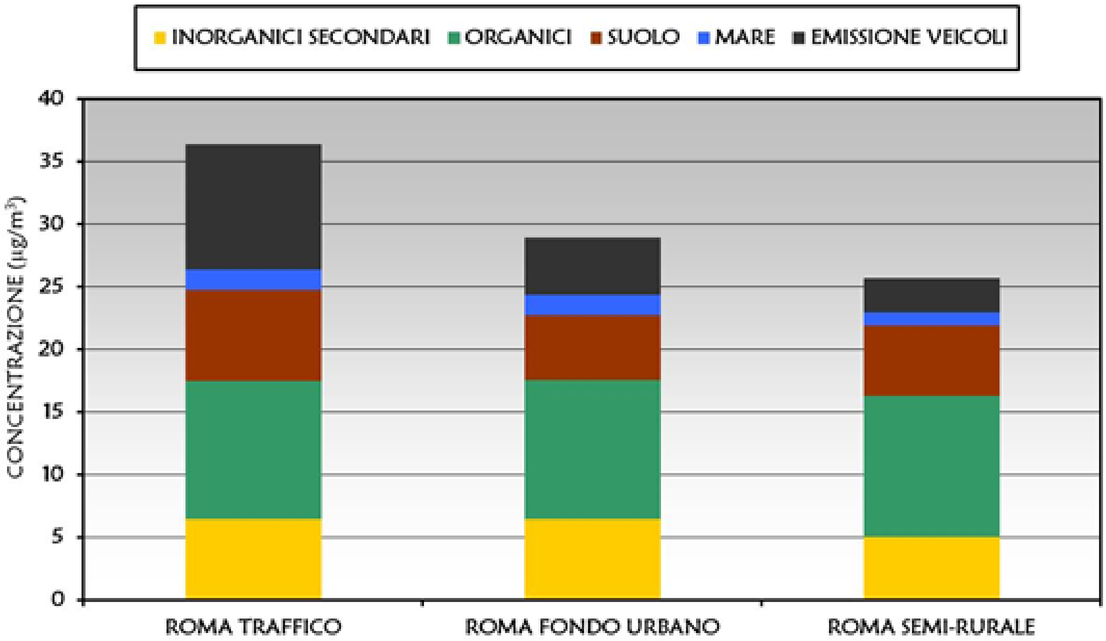


Figure 10 – Average composition of PM_{10} in three stations in the urban and peri-urban area of Rome (year 2011).

Based on the foregoing considerations, it can be understood how the lock-down had very significant effects on the NO_2 concentration, which is emitted almost exclusively by the traffic and plants of heating, while the effects on the concentration of PM_{10} have been a lot less important, and generally visible especially during the month of April. Is in fact it should be considered that the blocking of mobility had no effect on the natural sources of PM (sea, soil and part of the organic), nor on heating emissions, which significantly influenced the results of the month of March. We must also consider that in March it was including a first decade of pre-lock-down, a period of strong stability atmospheric, which increased the production of secondary species, and a phenomenon of sand transport from the desert areas of the Caspian Sea, which of course it has no connection with local mobility. During the month in April, on the other hand, with the heating almost completely off, thanks to the mildness of the season, it was possible to highlight a decrease in concentration of PM_{10} which in the cities of Rome and Naples was between 20 and 30%. This value is an estimate of the contribution due to the traffic and provides an indication of the results that can be achieved implementing policies to effectively reduce mobility.

In conclusion, citizens' mobility during the lock-down period in the urban areas of Turin, Milan, Rome and Naples it decreased significantly, with a percentage reduction in movements, compared to pre-lock-down, between 60and 95%.

This significant decrease in mobility caused a decrease important of the NO_2 concentration in the measuring stations defined as "monitoring traffic stations". Compared to the same period of the year in the four-year period 2016-2019, the decrease, on a monthly basis, was 30-60% in March and

40–70% in April, the period least affected by emissions from heating which, together with traffic emissions, constitute the main source of NO_2.

For PM_{10}, on the other hand, the reductions in concentration were much lower and, especially in March, often not observable. This is due to the complex chemical nature of the atmospheric particulate material, which includes fractions, including those of natural origin, not affected by traffic emissions. For the cities of Rome and Naples, during the month of April it was possible to appreciate a certain reduction compared to the four-year period reference, also in the concentration of PM_{10}, reduction which however, on monthly basis, did not exceed 27%. The influence of local natural contributions, long-distance transport and atmospheric stability conditions, which they favor the formation of secondary species, make obtaining critical of significant reductions in the concentration of PM_{10} even in conditions of extreme reduction in mobility, such as those that occurred during the period of the lock-down.

A certainly more significant reduction effect can be obtained for the finer fractions of atmospheric particulate matter ($PM_{2,5}$ or even lower fractions), which are more modestly affected by natural contributions and for which vehicular traffic, together with domestic heating, constitutes one source of primary importance.

Electric mobility penetration scenarios in Italy and comparison with the European context

Edited by Dino Marcozzi e Francasco Naso

Year zero

For European car manufacturers, 2020 will certainly be remembered as the "annus horribilis" under an "overall sales" perspective, with percentages of reduction between 20 and 30% due to the lockdown, but certainly also as the year of the definitive start of the electric vehicle market. All car manufacturers have in fact recorded exponential increases in sales: Volkswagen alone announced that it had sold 212 thousand cars "on tap" (of which 134 thousand purely electric vehicles, + 197% compared to 2019). The precursor Tesla is still behind: with half a million electric cars sold, it has reached the goal that was set back in 2014 and looked upon with skepticism by many.

Italy, albeit with a delay of 2-3 years compared to other major European countries, has nevertheless gone beyond the rosiest forecasts with a final balance of 32,500 cars sold in the area in 2020.

The current market in Italy

The demand for electric vehicles is currently driven by dynamics that determine the speed of growth, linked to the perception of users in Italy, where, according to the latest surveys, almost 9 out of 10 respondents would buy an electric car[1]:

- **The advantages**: the main motivation is the environmental one, which testifies a sensitivity on the subject of air quality and climate warming that is growing all over the world. However, users also appreciate the economic advantages of operating electric vehicles, in terms of refueling, savings on road tax and parking, access to restricted traffic areas and maintenance costs. The positive experience is also determined by the test drives, that increasingly confirm the importance for Italians of quietness and a relaxed driving style, as well as performance even at low revs and even on popular segment cars (A or B).
- **The price**: Italian citizens still perceive the limit on the purchase price as decisive. If, on the one hand, this is linked to the low propensity of Italians to evaluate the whole life costs of the goods they purchase, on the other hand there is no doubt that the purchase prices still do not allow, despite the incentives, access to this type of solution to citizens belonging to the lowest income brackets. The unit margins of manufacturers are currently very low, if not non-existent, because they will have to distribute the development and reconfiguration costs of the very important lines and supply chains over a few units; for this reason, almost all manufacturers have started

1 Latest Areté poll: https://insideevs.it/photo/5336863/i-risultati-di-un-sondaggio-sul-rapporto-tra-gli-italiani-e-la-mobilita-sostenibile/

the development of cars of at least segment B and, in any case, aiming at price ranges from segment C in comparison with endothermic vehicles. In particular, the battery pack accounts for 40% of the cost of the vehicle, but the birth of new production poles, especially in Europe, is expected to bring the price down within 3 years below the threshold of 100 € / kWh, identified by more authoritative subjects as a fundamental objective for the breakeven purchase cost. Hence, it follows that the incentive policy will have to be continued beyond 2021 in order to allow the diffusion of vehicles in the Total market up to penetration percentages of 10-15%. This percentage is considered a fundamental target both for the creation of a widespread culture of the electric vehicle in the population and among companies, and to allow manufacturers to reach useful margins for lowering purchase prices. The various surveys show that users are still willing to spend 10% more for the purchase of an electric vehicle than for a thermal vehicle. At the level of Total Cost of ownership, on the other hand, already today some cases of use are advantageous for those who adopt the electric vehicle, both for M1 company fleets, for some private users with high annual mileage and ultimately for light commercial vehicles.

- **The recharging infrastructure**: this is the other dominant dynamic, especially for users of large cities where private vehicle storage is more difficult and the capillarity of public recharging, in particular of limited power, becomes decisive in favoring the adoption of pure electrical means. Central, therefore, will be a national planning that is shrewd and modulated over time, which cannot therefore be separated from a careful and radical revision of the PNIRE (National Plan of Infrastructures for Charging Electric Vehicles), which has long suffered a marked detachment from the dynamics of the charging infrastructure business. However, the surveys show that users have a poor perception of the use of their means of transport, also in terms of how long they keep it stationary (for more than 90% of the time) or the km they actually travel (more than 75% of the users of private means of transport cover a daily distance of less than 25km), as well as the radical change that electric vehicles bring to refueling methods, being able to take advantage of the stops to recharge the vehicle while doing other activities. At the same time, however, there is a need for a widespread network of high-power recharges, the so-called fast and ultra-fast (from 50 kW upwards), which allow 80% recharging even in less than 10 minutes and enable the use of the electric vehicle as the only private vehicle of a family or a business. This network must quickly be built on the motorway and on the main routes, but also in the urban area, paying particular attention to the choice of installation sites (e.g. railway stations, fuel distributors, etc.). A separate discussion should also be made on logistics, in particular of the last mile, in order to be able to electrify even freight vehicles in urban areas that need a dedicated charging network, also at high power. In any case range anxiety, the anxiety of autonomy, is slowly diminishing thanks to the technological improvements of the batteries that are allowing significant increases in both energy density and power, and therefore autonomy and consumption, as well as recharging power.

- **Availability of models**: the number of models is destined to grow.

Although it was slowed down by the pandemic, the release of models for the mass market actually took place with the presentation, among others, of the 500e (which immediately jumped to first place in December among the electric cars sold in Italy) and the VW ID.3. (dominatrix in the European market). More than 80 models are expected to be presented in the next 3 years, which will increase the choice for users and consequently increase the propensity to buy. However, the availability of means will be decisive in terms of volumes and delivery times: the birth of new production lines and the increase in production volumes will determine the speed of growth of BEVs (Battery Electric Vehicles) and PHEVs (Plug-ins Hybrid) in circulation.

Turning to the final balance for the year 2020, which is summarized in Figure 5.1, numbers show the great development that is taking place in the two "on tap" engines, despite a dramatic reduction in the overall market (- 27.9%)

ANALISI DI MERCATO	Dicembre 2020	Dicembre 2019	Diff. Mese %	YTD 2020	YTD 2019	Diff. YTD %
BEV	7,258	856	747,90%	32,500	10,728	202,95%
PHEV	6,354	695	814,24%	27,375	6,306	334,11%
BEV+ PHEV	13,612	1,551	777,63%	59,875	17,034	251,50%
Percentuale su tutte le alimentazioni	11,41%	1,10%	10,31%	4,33%	0,89%	3,44%
Tutte le alimentazioni	**119,304**	**140,854**	**-15,30%**	**1.383,54**	**1.919,303**	**-27,91%**

BEV – Battery Electric Vehicle, cars characterized by an electric motor, therefore powered by batteries.
PHEV – Plug-in Hybrid Electric Vehicle, characterized by both electric and internal combustion propulsion.

Table 5.1 Final data for 2020 sales and comparisons with 2019
Source: Motus-E

As regards the distribution segments in Italy (Figure 5.2), the effect of COVID has led to a decrease in the incidence of fleets, i.e. cars purchased by companies, and long-term rental (although growing respectively by 60% and 185% respectively) to the benefit of a development of the private channel which rises by 253%. The self-registrations of BEV and PHEV also rise, both above 300%, due to the significant increase in new models to be tested by customers and the short-term rental that finally and deservingly, despite the moment of great difficulty, is inserting vehicles "on tap" in his fleet.

DISTRIBUZIONE NUOVE IMMATRICOLAZIONI AUTO ELETTRICHE

	Anno 2020	**Anno 2019**
PRIVATI	23,028	5,685
FLOTTE AZIENDALI	4,661	2,531
RIVENDITORI	9,675	2,103
NOLEGGIO (Lungo Termine)	20,725	6,147
NOLEGGIO (Breve Termine)	1,786	568
TOTALE	**59,875**	**17,034**

Table 5.2 Final data for 2020 distribution segments and comparisons with 2019
Source: Motus-E https://www.motus-e.org/analisi-di-mercato/dicembre-2020-la-rivoluzione che-non-si-ferma

In summary, while the PHEV market is developing with many new models, the BEV market is still strongly influenced by production and delivery policies that still do not reach a mass market regime. For example, Tesla places the European market behind the American and Asian ones, pending the production of the German Gigafactory, which will mark a further boost on some European markets, in particular the Italian one.

Italian scenarios in 2030

Motus-E has developed electric vehicle penetration scenarios based on the decarbonization objectives presented in the PNIEC by the Government. It should be considered that the PNIEC itself will be subject to review in the next 2 years, based on further restrictions on greenhouse gas emissions (from 38 to 55%) by the EU; this will lead to a further increase in the penetration of electric mobility, compared to what is seen in the current scenario.

The developed scenario takes into account current market trends, the substantial reduction in the cost of purely electric vehicles and the development of charging infrastructures, while representing a trend of progressive lower participation in the transition by plug-in hybrid vehicles. It should be emphasized that this scenario represents a very important step to reach, if not to exceed, the target of 21.6% of consumption from renewable sources and a reduction in consumption of 2.6 Mtoe in transport. The scenarios relating to vehicles for light goods transport (LCV), public transport (TPL) and heavy goods transport (HGV) are also reported.

A market for new registrations has been assumed that is substantially constant over time for both private cars and LCVs, favored by policies to support the replacement of company vehicles and the scrapping of polluting private vehicles, but also by local policies on the circulation of private vehicles, in particular internal combustion in urban centers and rules for the development

of modal shifting between local public transport, sharing mobility and soft mobility, of an electric matrix.
That of TPL and HGV vehicles, on the other hand, is both growing due to the need for a replacement of the fleet that discounts vehicles with a high average age (11.4 years for TPL, 4 years above the European average). The electrification of public transportation by road will be central both as an example to private individuals and to increase the quality of public service and attract passengers; on the other hand, the adoption of battery electric technology for heavy goods transport vehicles is still considered less likely.

It is evident that electric technology is easier to adopt in some specific applications, such as LCVs for last mile logistics, or for urban LPT, where, probably by 2030, new registrations for the purely urban context could reach 100% electric vehicles.

Focusing on M1 vehicles, Figure 5.3 shows the numerical developments of registrations and circulating of BEV and PHEV cars based on the objectives set with the Integrated National Plan for Energy and Climate and the work carried out in the Tables of MOTUS-E work; objectives, those of the Government by 2030 of 4 million BEV and 2 million PHEV, which can be achieved with the annual registration values shown in the table.

	2021	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
BEV	60,000	110,000	170,000	280,000	450,000	500,000	600,000	700,000	850,000	1.000,000
PHEV	40,000	60,000	90,000	110,000	130,000	150,000	160,000	200,000	250,000	300,000
TOTAL MRKT(M)	1,78	1,83	1,87	1,91	1,93	1,94	1,94	1,94	1,93	1,92
% BEV	3%	6%	9%	15%	23%	26%	31%	36%	44%	52%
%PHEV	2%	3%	5%	6%	7%	8%	8%	10%	13%	16%
Car fleet without BEV	116,400	223,100	397,700	669,300	1.105,800	1.590,800	2.172,800	2.851,800	3.676,300	4.646,300

Table 5.3 Numeric developments in registrations and in circulation of M1 vehicles
Source: Motus-E

However, it is important to understand that these values are challenging to say the least: some scenarios, based on the current industrial plans of European companies and on very conservative forecasts on the tools to support demand and infrastructures, report annual registration values (and consequence of circulating by 2030) which are decidedly lower than the PNIEC targets: for example IHS Markit, in a study for MOTUS-E reports, in a scenario of mild and short support and limited growth of the Charging Infrastructures, precisely, circulating by 2030 just under 1.8 million BEV and 0.9 million PHEV, as shown in the graph in Figure 5.4.

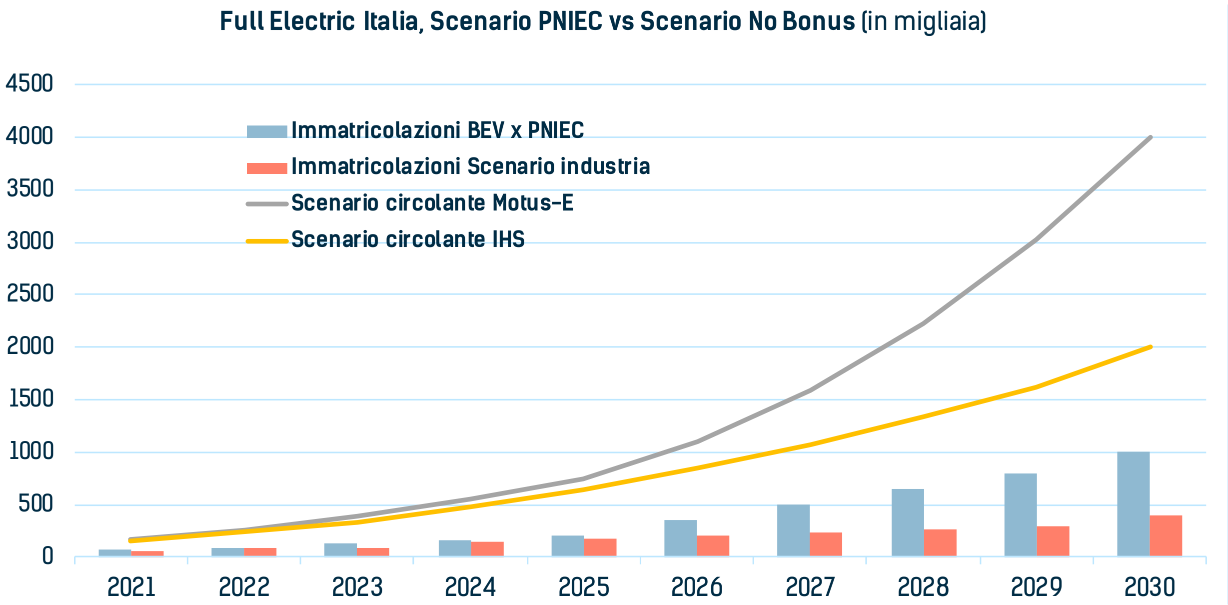


Fig 5.4 Trends in registrations and in circulation M1 BEV

It is also relevant to highlight that all scenarios do not provide for the mere replacement of the current 39 million private passenger vehicles powered by fossil fuels with vehicles "on tap". But it will be inevitable and to be accompanied by the institutions to decongest our roads and reduce the volume of private cars in favor of an expansion of other modes of transport
.
The significant reduction of the circulating fleet, which transforms our streets into parking lots (remember that the average use rate of cars in Italy is 5%), will take place if we invest in the paradigm shift towards Mobility as a Service, with the positive reflex to increase the rate of use of private vehicles, going beyond the concept of owned vehicle, as it's happening in other European countries. This dynamic could also have effects on purchases of new vehicles, which reached an all-time low in 2020 due to the pandemic (1.35 million vehicles sold, -27% compared to 2019) and which could find it difficult to return to pre-pandemic levels, with harmful consequences on the working capital which will increase its average age and, intrinsically, its environmental impact. We therefore reiterate the importance of maintaining support for the demand for new zero-emission vehicles for a few years, in order to encourage a replacement that is increasingly necessary. From this point of view, certainly the penetration of electric vehicles and the relationship between pure electric and plug-in within the PNIEC seems unrealistic compared to the decarbonization objectives that are set. For these reasons, we have built **a scenario that limits the volume of the fleet to 32 million vehicles.**

This value is calculated by keeping the number of new annual registrations constant, (about 2 million) against an increase in the replacement rate, which goes from the current 3.5% to 8%. In fact, suppose that in the years to come all car classes below EURO 4, which make up about 40% of the current fleet, will have serious restrictions or bans on access in urban contexts, causing a circulation problem for these vehicles, which should be replaced or scrapped.

With a parallel massive expansion of urban and peri-urban LPT it would be possible to change the way people travel and to be able to lower the motorization rate in Italy, which is among the highest in Europe, of 0.662 cars / inhabitant, which means 2 vehicles for every 3 inhabitants (of any age group). It is therefore essential to support the electrification of company fleets and the growing ones of rental and mobility services, while the reduction of private circulation must be accompanied, especially through the disposal of polluting vehicles but also through the dissemination and standardization of local policies on access to urban centers and on parking, together with a review of the taxes for the use of polluting vehicles.

A look at the current European context

In Europe, the impressive race for electric continues.
The key figure is the achievement of one million BEV + PHEV cars registered in 2020 (Fig. 5.5 the growth in sales in the global European geographical area.)

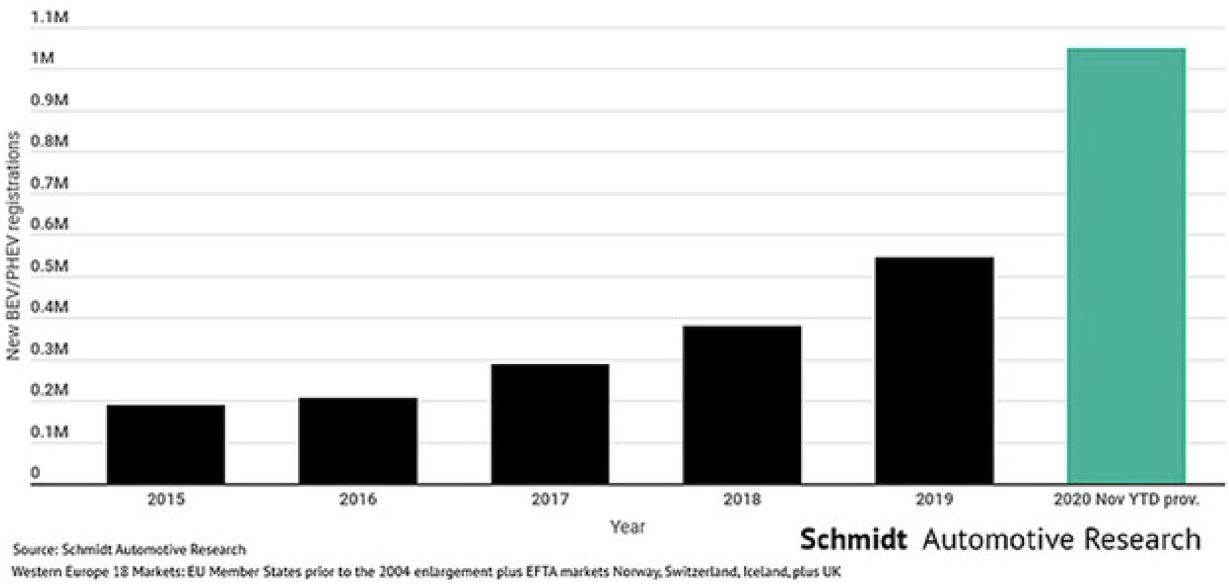


Fig. 5.5 BEV + PHEV registrations in Europe, total geographical area 2015 – 2016
Fonte: "Schmidt Automotive Research"

In Germany, the largest European market in terms of electric vehicle registrations, 43,671 BEVs were registered in December 2020 with a growth of 660% compared to the corresponding December 2019. Since the beginning of the year 194,163 BEVs have been registered in Germany (six times than in Italy).

In the Netherlands, in November 2020, BEVs accounted for 49% of the total market, also thanks to a favorable environment generated by the most widespread and developed charging infrastructure network in Europe. To get an idea of the growth, consider that in December the first four cars sold (in the overall market) were four BEVs: ID.3, Kona, Model 3, ID.4

In France, BEVs exceed 100,000 units registered in 2020, consolidating it as the second largest electric market in Europe.

Therefore, not only the Nordic markets (Norway, Sweden) but also the mass markets similar to Italy, while denouncing the same global crisis in car sales (-26.5%), show a transition towards electricity which is about to take place, detaching more and more from our country. This gap must worry those who care about sustainability, considering that the limits to exhaust emissions on newly registered cars are continental limits, not national ones. Therefore, due to delayed policies in our country, there will be an increasing temptation for manufacturers to reserve marginal production quotas of fossil cars for Italy.

Motus-E and CNR-IIA proposals for Electric Mobility

With the aim of increasing the well-being of citizens both in terms of air quality and therefore health, the electrification of city mobility represents one of the technological solutions to be applied decisively and represents a valid contribution to the decarbonization of the transport sector compared to fossil fuels.

It is therefore necessary to implement new and more incisive actions at national and local level, below are the proposals by Motus-E and the CNR-IIA:

1. **Set a deadline for the sale of endothermic cars**: a European target remains necessary for stopping the sales of internal combustion cars with increasing annual quotas.

2. **Strengthen city networks** (of electricity distribution, of data transmission, road, local public transport, vehicle charging) following a Smart City model and interconnect them in their exchange nodes as they are decisive for both the electrification of passenger and freight transport.

3. **Private Cars**: it is essential that the demand for zero and low emission M, N and L vehicles (below 60 gCO_2 / km) is sustained and that, with a view to continuity and certainty of the instruments, the structure currently envisaged is maintained. for the eco-bonus, extending its validity until 2025 and maintaining the form of the direct purchase incentive. However, a strong reduction in the use of private cars in an urban environment is considered essential and therefore it must be a fundamental objective of local and national institutions to lower the motorization rate, today among the highest in the world (65 cars per 100 inhabitants).

4. **Public Transport: there is a need for a replacement of the local public transport fleet by road with zero-emission vehicles** which ASSTRA and ANEV estimate to be three times the allocation of the National Strategic Plan for Sustainable Mobility, which already amounts to 3.9 billion up to 2033.

5. **Prepare a sustainable urban logistics of goods with low impact** and electric vehicles in agreement with the operators. Promotion of electric vehicles with reward systems on the rules of access to LTZ.

6. **Identify a Fund** for the development of a national network of public access charging infrastructures.

7. **Implement charging infrastructures in logistics centers** and in freight vehicle garages, accompanying the trend of electrification of freight transport, in a first phase of light goods vehicles of urban logistics and in a second phase of trucks for medium and long haul.

8. **Review the Ministerial Guidelines on SUMPs** and integrate the electrification of vehicles as a measure for improving air quality in cities more in Urban Plans.

9. **As part of the National Recovery and Resilience Plan (PNRR) to access Next Generation EU (NGEU) funds, to request greater investments for an adequate urban and regional electric mobility network**, at the moment there is no specific item on the development of an adequate national electric charging network for public use, no investment for the industrial conversion of the transport sector, crumbs for road safety.

10. **Investing in the automotive industry** for the conversion of sectors involved in the transformation of vehicles and electrical infrastructures (electrical and electronic components, digitization of vehicles and C-ITS, SW platforms for new services).

11. **Enhance scientific studies on the sources of atmospheric pollution,** on the chemical composition of particulate matter and on emerging pollutants (including nanoparticles) to fully understand the phenomena and the main sources of emissions on which to intervene.

12. **Extend investigations into epidemiological correlations** and health effects and thereby establish a relationship between emissions of pollutants in all influential sectors and the effects on human health and economic impacts. The goal is to enhance the collection, analysis and research on air quality, related phenomena and health effects.

13. **Implement the Action Plan contained within the Clean Air Protocol** signed in Turin at the beginning of June 2019 and divided into 5 areas of intervention establishing an air pollution control fund.

Environmental and health benefits associated with electric mobility for the contribution to the achievement of the programmatic objectives

Turin

In this case, the vehicle fleet consists of only the two sectors of private transport and logistics. Both Local Public Transport and all other types of vehicles (motorcycles, heavy vehicles, etc.) and other emission sources are excluded from the study. About the baseline scenario, concerning the vehicle fleet, the two most common categories, for the private sector, are petrol vehicles and diesel vehicles, mainly of the environmental class Euro 4, Euro 5 and Euro 6, with a percentage respectively of 48% and 40%. The other technologies, although present, are in much lower percentages. It shows a complete lack of electric vehicles.

As regards the logistics sector, the most widespread technology is the diesel category, present with a percentage of 85% and mainly Euro 0 class vehicles.

Referring to the hypothesized scenarios, the first scenario (Scenario 2025), is less favorable about the diffusion of electric vehicles, is configured assuming an increase of 4% in the number of private vehicles and greater penetration of hybrid cars (about 20%), with EURO 5 and EURO 6 homologated cars. For the logistics sector, penetration of electric vehicles equal to 5% and hybrid vehicles equal to 15% is supposed.

The second scenario presents a greater incidence of electric cars equal to 20% and hybrids equal to 50% by 2030, meanwhile, the vehicle fleet (the number of total vehicles) remains constant, i.e. equal to the 2025 scenario, but with only EURO 6 homologated cars. For the logistics sector, the percentages relating to electric vehicles reach 15% and those relating to hybrid vehicles reach 25%.

NO_2 Concentrations

The average hourly concentrations simulated reach a maximum of about 130 µg/m^3 in the baseline scenario. In future scenarios we observe a net reduction, going from a percentage of 50% by 2025 to a percentage of 87% by 2030. In terms of concentration differences, in the 2025 scenario, there are reductions of up to a maximum of 58 µg/m^3 compared to the baseline scenario, meanwhile comparing the 2025 scenario with the 2030 scenario, a constant reduction is evident and the maximum reached is equal to 53µg/m^3 .

PM_{10} Concetrations

In the basic scenario, the daily concentration values of PM10 reach a maximum of about 23 µg/m^3. The areas most affected by the contribution of the private vehicle fleet are concentrated in the road--link with the greatest traffic flows. In future scenarios we observe a net reduction, going from a percentage of 35% by 2025 to a not very significant reduction of 36% by 2030. In terms of concentration differences, by 2025 there are reductions up to a maximum of 7.5 µg/m^3 compared to the baseline scenario, furthermore comparing the 2025 scenario with the 2030 scenario, there is a little significant difference, less than 1 µg/m^3.

Health and economic impact

Using the simulated concentration values, only in the traffic control units at rush hour (8 am) in the winter period (January), with ADMSRoads and implementing the data in the BenMap software for each pollutant analyzed, PM_{10} and NO_2 and for each hypothesized scenario, the number of premature deaths due to the short-term effects relating only to the transport sector was estimated and the related associated cost was estimated.

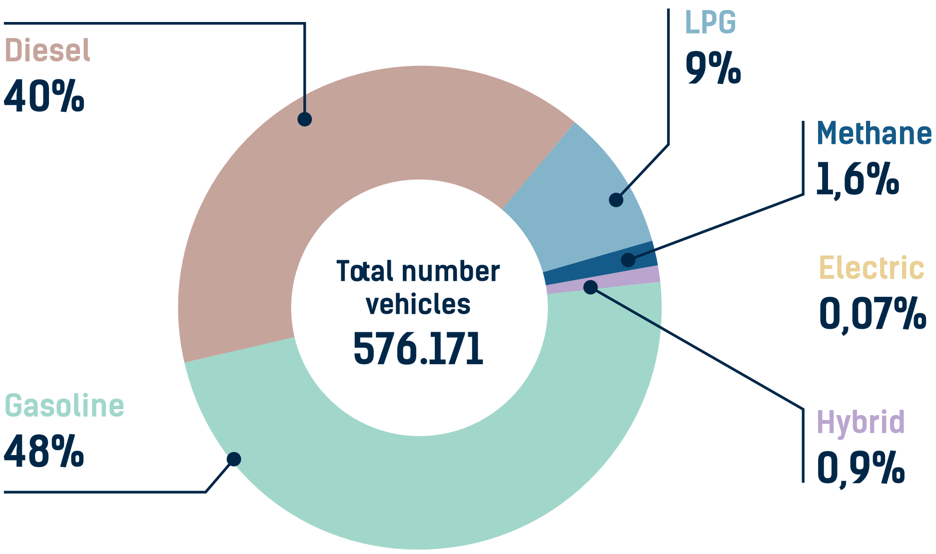
	Base Scenario		**2025 Scenario**		**2030 Scenario**	
	PM_{10}	NO_2	PM_{10}	NO_2	PM_{10}	NO_2
Number of premature deaths (N)	63	166	41	83	40	22
VSL (million euros)	240	630	155	315	153	82

Turin

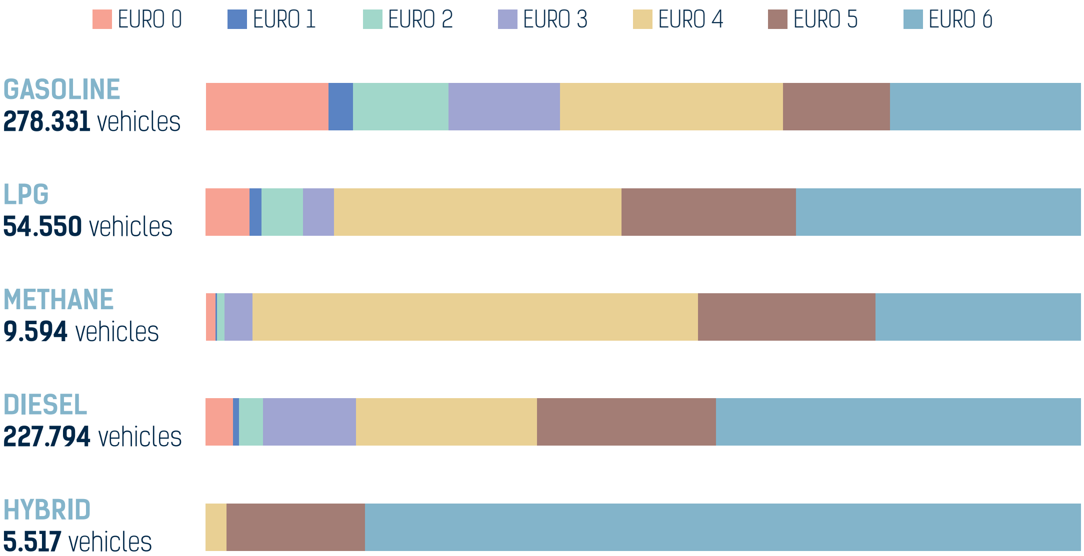
Passenger cars fleet

2018 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	63	166
VSL (million euros)	240	630

Electric Vehicles

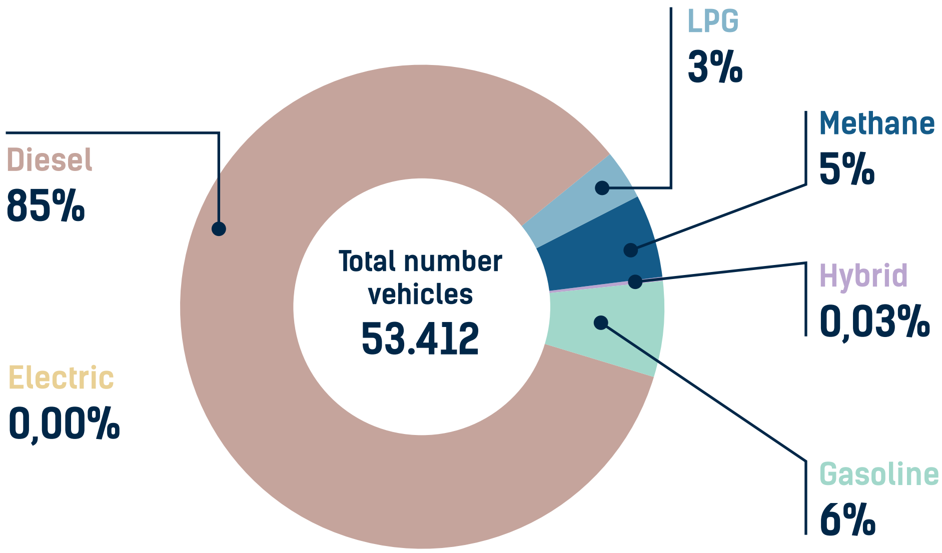
385

0,07% out of total number of vehicles

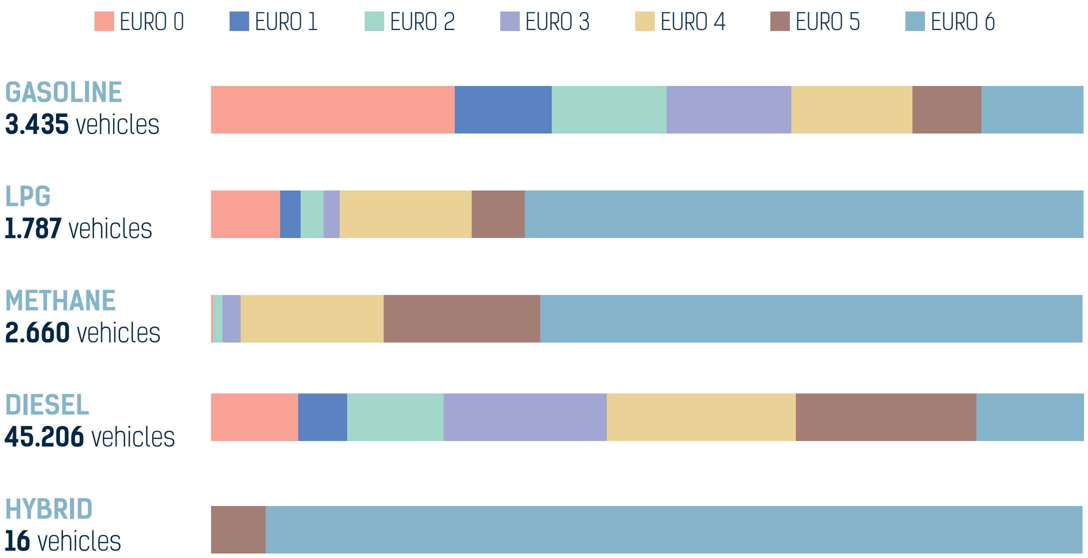
Turin

Logistics vehicle fleet

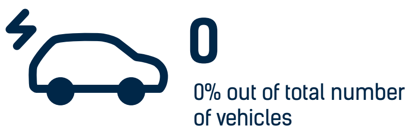
2018 Scenario



Segregation for Euro class



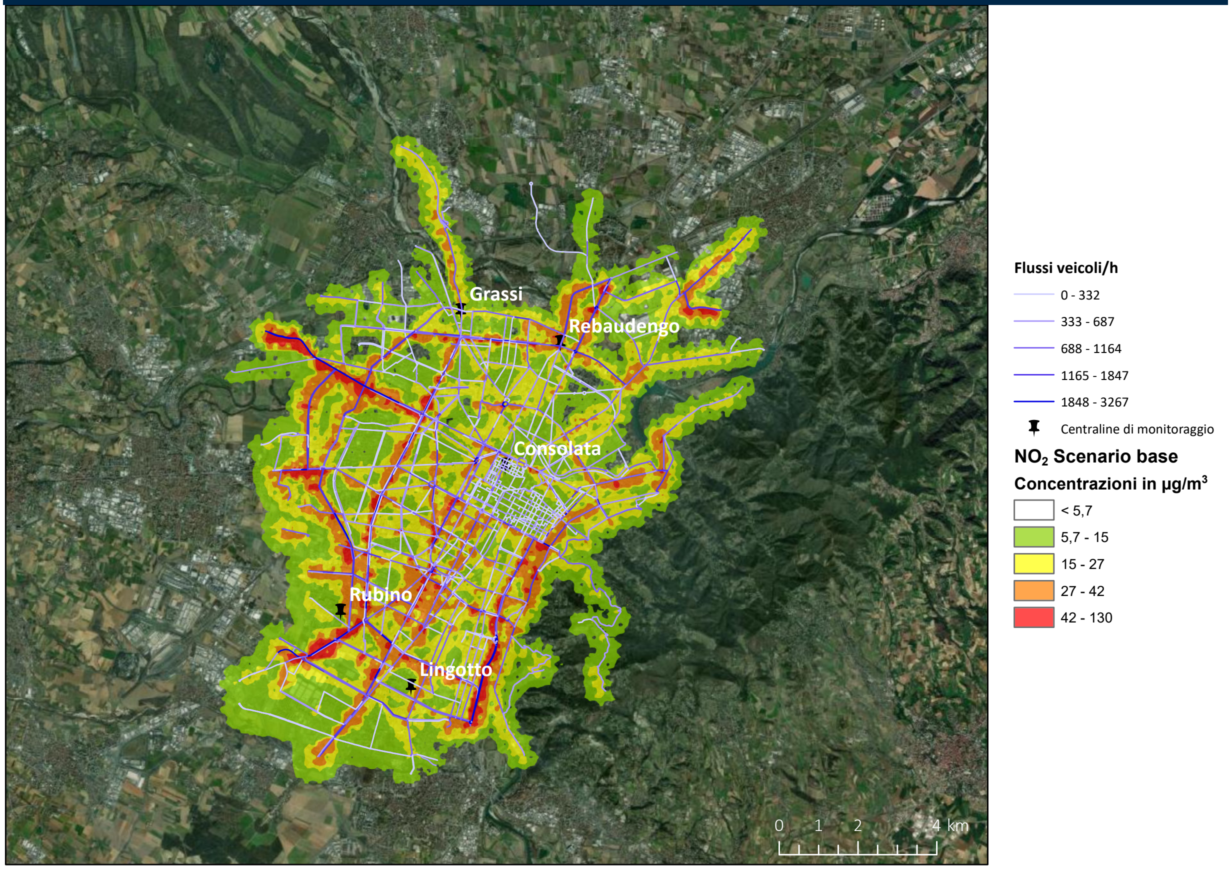
Electric Vehicles

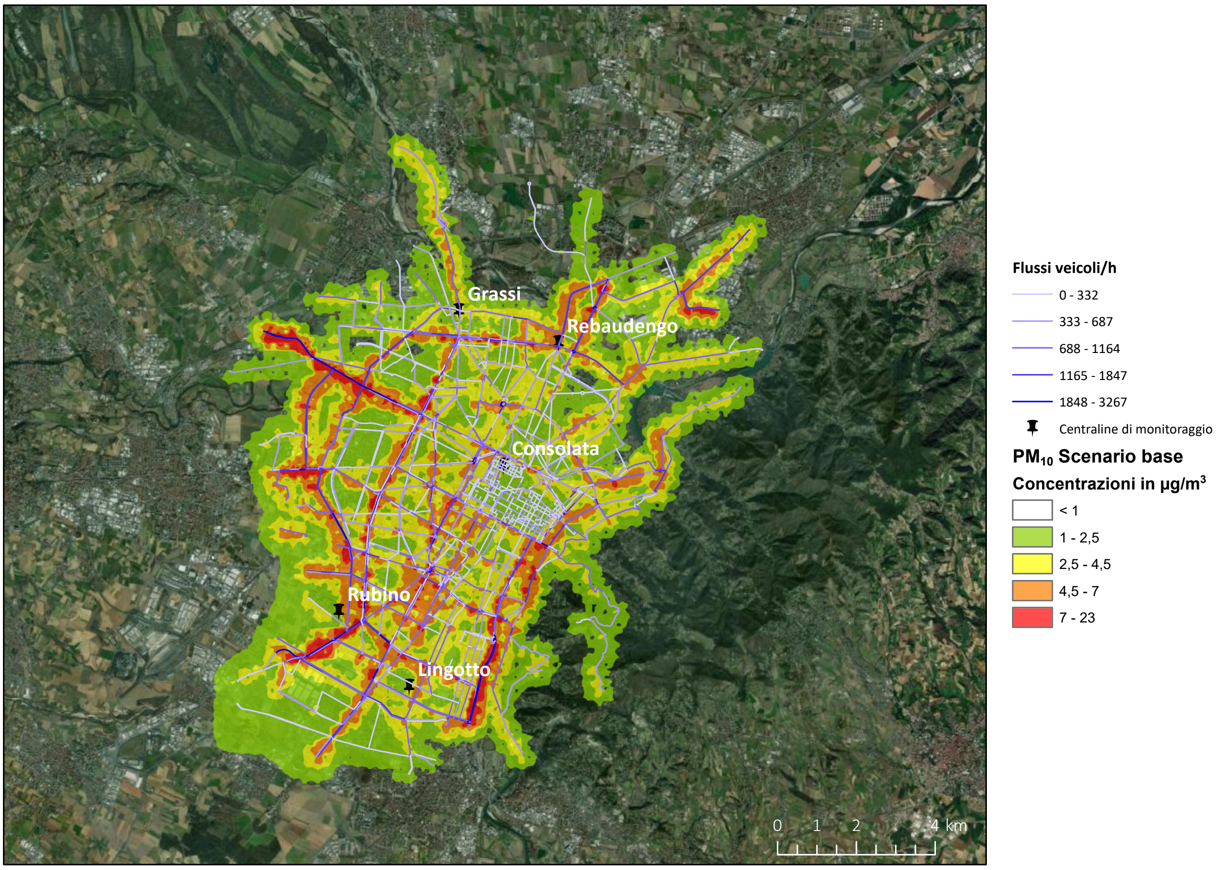


Turin

Air quality

2018 Scenario



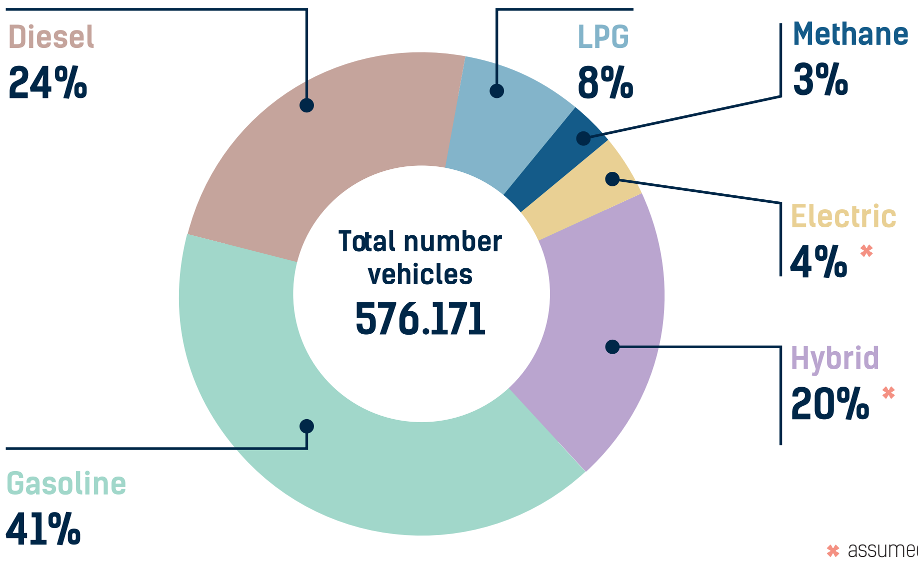


Turin

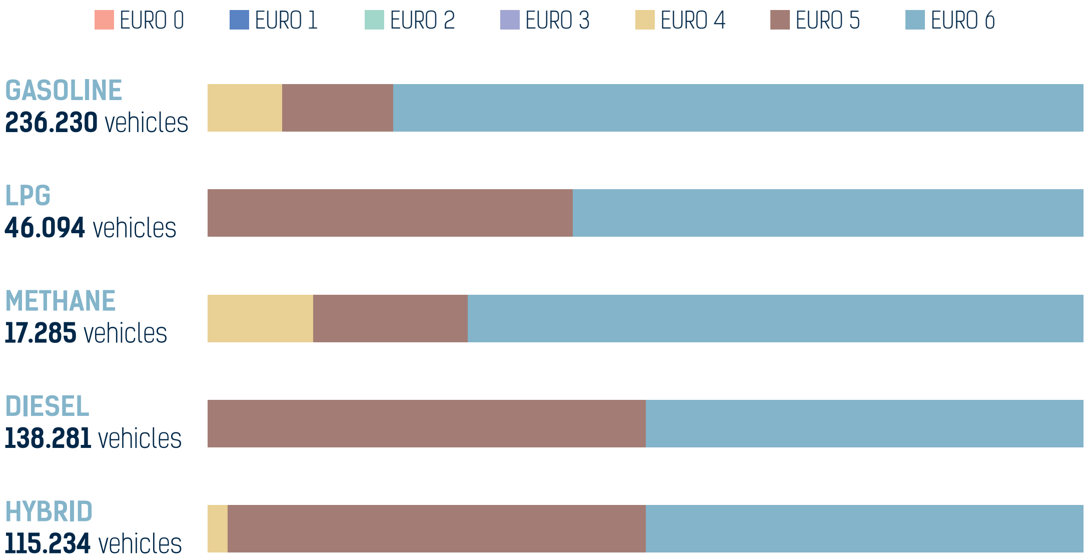
Passenger cars fleet

2025 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature de aths	41	83
VSL (million euros)	155	315

Electric Vehicles

23.047

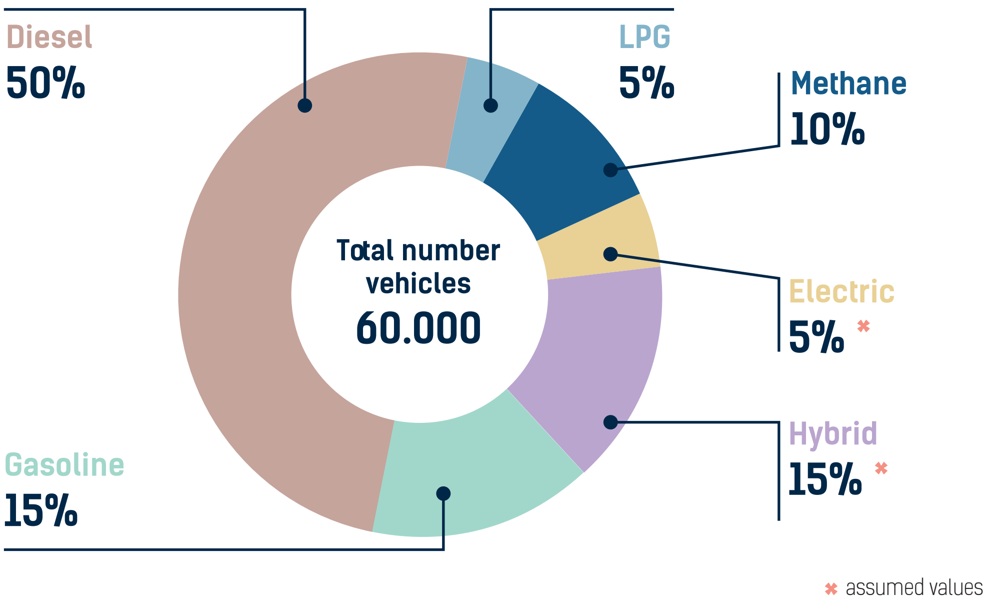
4% out of total number of vehicles

Turin

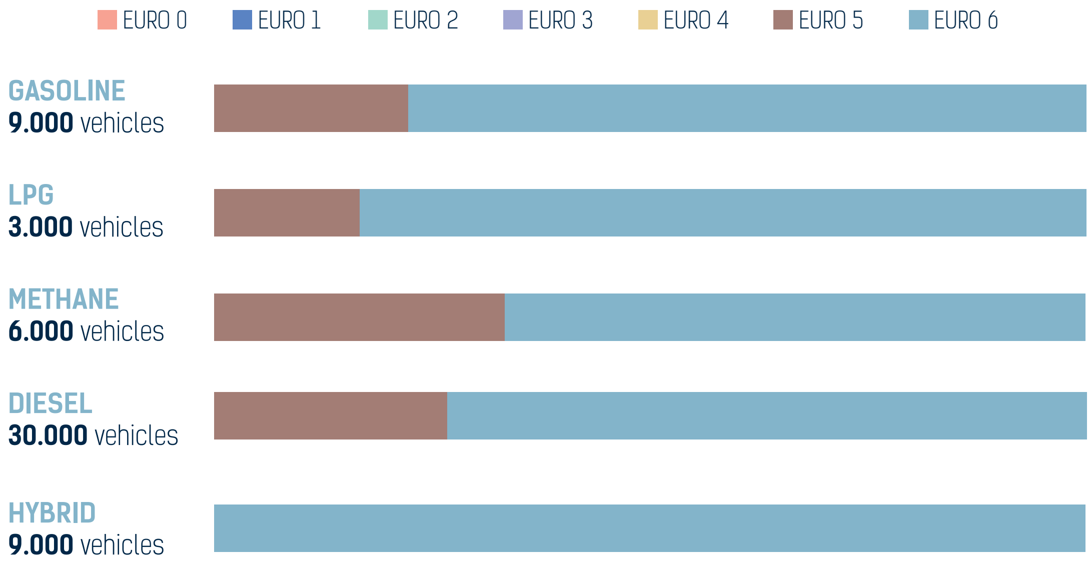
Logistics vehicle fleet

2025 Scenario

Segregation for fuel type



Segregation for Euro class



Electric Vehicles

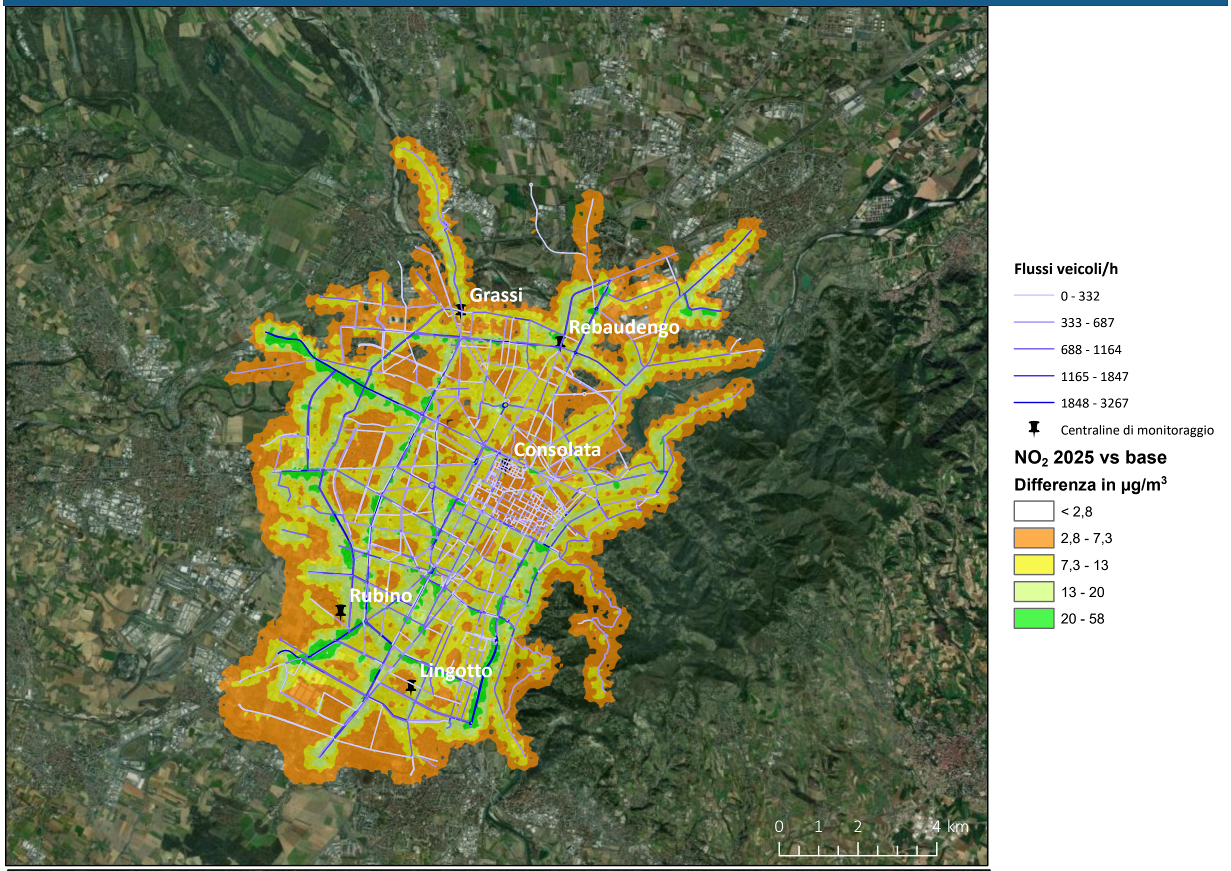
3.000

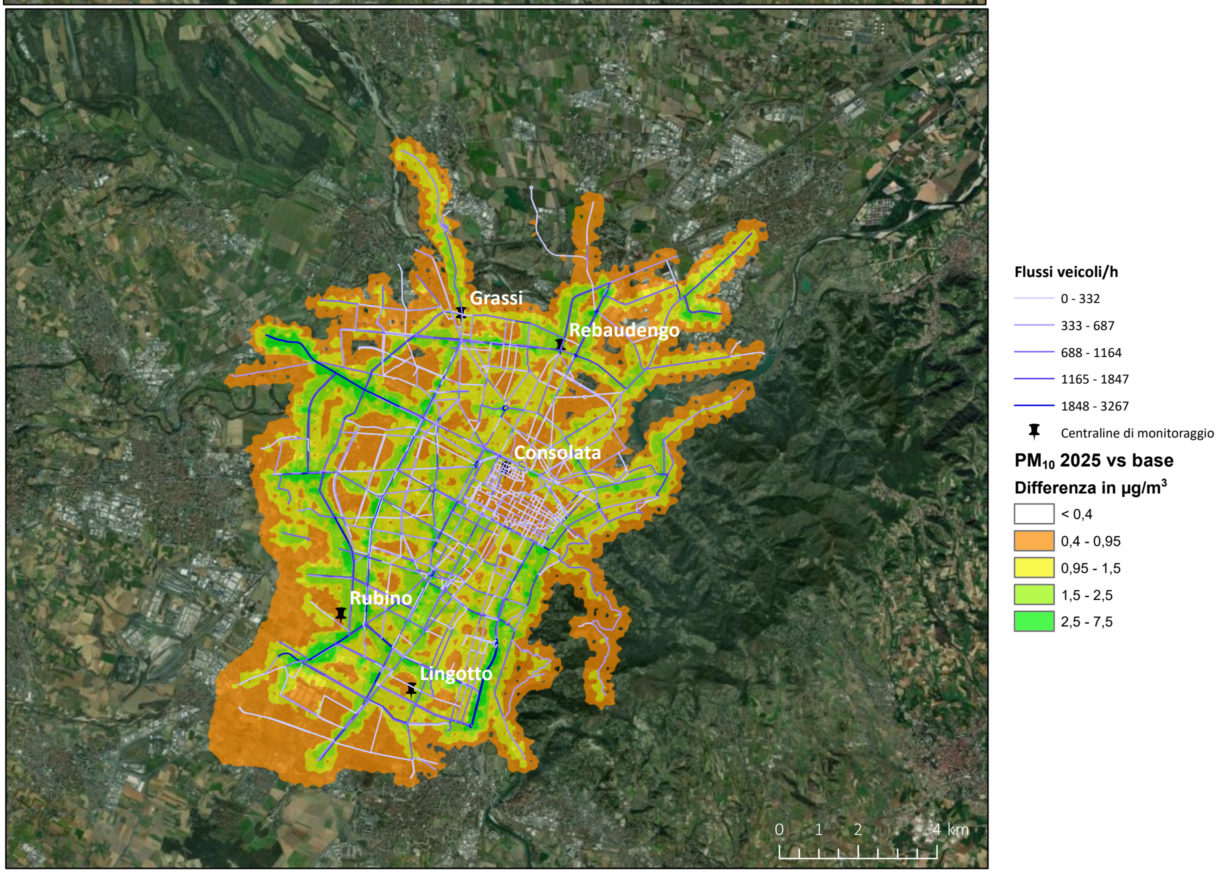
5% out of total number of vehicles

Turin

Air quality

2025 Scenario





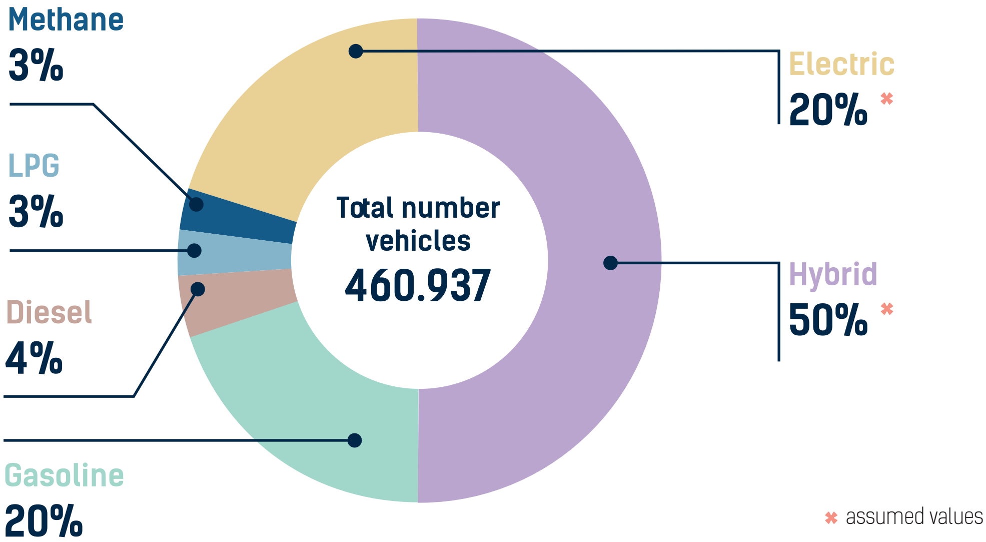
Turin

Passenger cars fleet

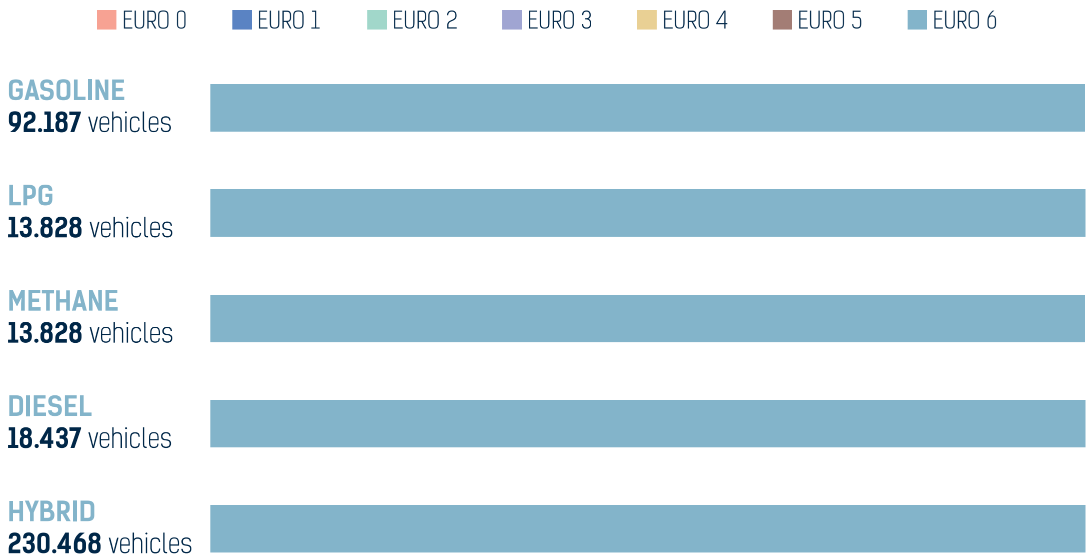
2030 Scenario

Segregation for fuel type

Total circulating fleet reduced by 20%



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	40	22
VSL (million euro s)	153	82

Electric Vehicles

92.18 7

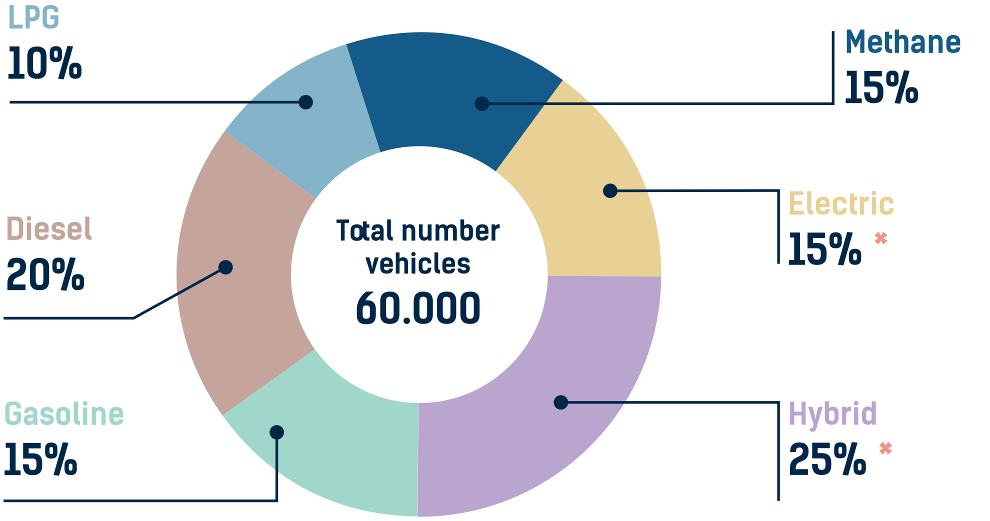
20% out of total number of vehicles

Turin

Logistics vehicle fleet

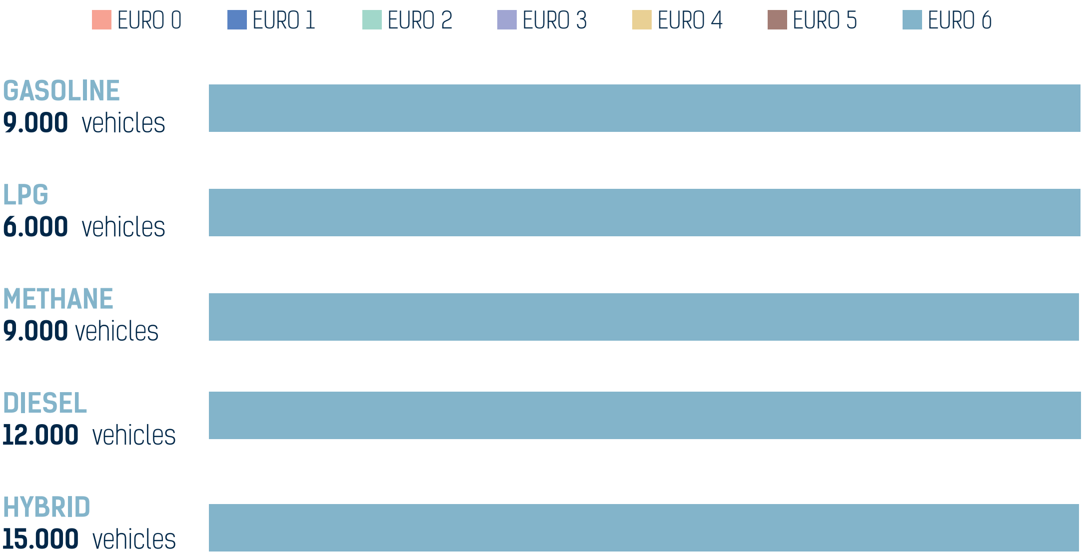
2030 Scenario

Segregation for fuel type



* assumed values

Segregation for Euro class



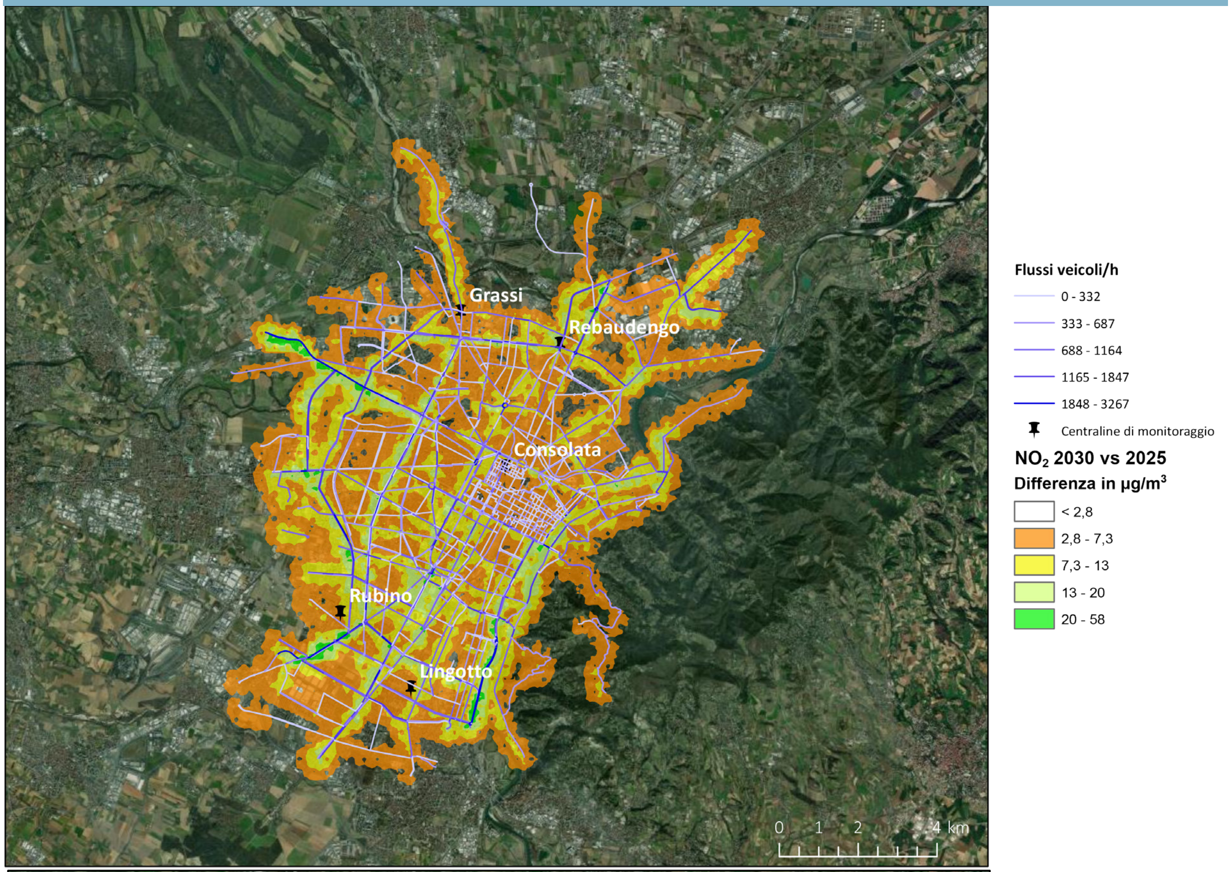
Electric Vehicles

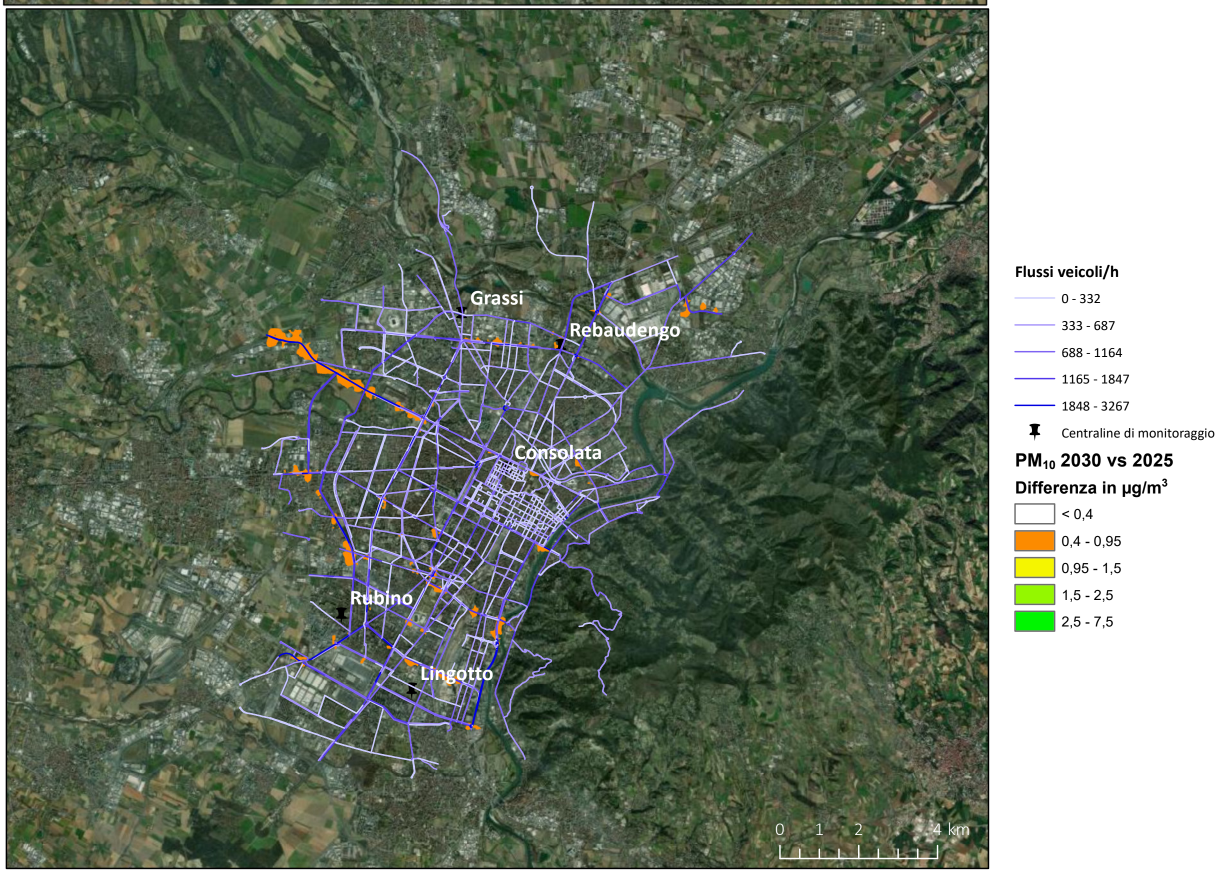
9.000
15% out of total number of vehicles

Turin

Air quality

2030 Scenario





Bologna

In this case, the vehicle fleet consists of only the two sectors of private transport and logistics. Both Local Public Transport and all other types of vehicles (motorcycles, heavy vehicles, etc.) and other emission sources not subject to study are excluded from the study.

In relation to the basic scenario, as regards the vehicle fleet, it is noted that the two categories most present, for the private sector, are petrol vehicles and diesel vehicles, mainly of the environmental class Euro 4, Euro 5 and Euro 6, with a percentage of 46% and 36% respectively. The other technologies, although present, are in much lower percentages. Note the complete absence of electric vehicles.

In relation to the logistics sector, the most widespread technology is that relating to diesel vehicles, present with a percentage of 83% and mainly Euro 0 class vehicles.

Referring to the hypothesized scenarios, the first scenario (2025 Scenario), is less favorable with regard to the diffusion of electric vehicles, is configured assuming an increase of 4% in the number of private vehicles and a greater penetration of hybrid cars (about 20%), with EURO 5 and EURO 6 homologated cars. For the logistics sector a penetration of electric vehicles equal to 5% and hybrid vehicles equal to 15% is expected.

The second scenario envisages a greater incidence of electric cars equal to 20% and hybrids equal to 50% by 2030, making the vehicle fleet (the number of total vehicles) remain constant, i.e., equal to the 2025 scenario, but with only EURO 6 homologated cars. With reference to the fleet of logistics vehicles, the percentages relating to electric vehicles reach 15% and those relating to the hybrid reach 25%.

NO_2 Concentrations

The simulated hourly average concentrations reach a maximum of about 150 μg/m^3 in the base scenario.

In future scenarios we are witnessing a net reduction, going from a percentage of 47% by 2025 to a reduction of 79% by 2030.
In terms of concentration differences, in 2025 there are reductions of up to a maximum of 61 μg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030, a decrease is noted which in any case reaches a maximum of 49 μg/m^3.

PM_{10} Concentrations

In the base scenario it is clear that the daily values of PM_{10} reach a maximum of about 15 μg/m^3. The areas most affected by the contribution of the vehicle fleet are those in which the arches with the greatest traffic flows fall.

There is a reduction in concentrations, passing from the 2025 scenario to the 2030 scenario, of 28% and 34% respectively. In terms of concentration differences, in 2025 there are reductions of up to a maximum of 6 μg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030 there is a not very significant difference, between 0.2 and 0.65 μg/m^3.

Health and economic impact

Using the simulated concentration values, only in the traffic control units at rush hour (8 am) in the winter period (January), with ADMSRoads and implementing the data in the BenMap software for each pollutant analyzed, PM_{10} and NO_2, and for each hypothesized scenario was estimated the number of premature deaths associated with the short-term effects of PM_{10} and NO_2, considering only the transport sector, and the related associated cost was estimated..

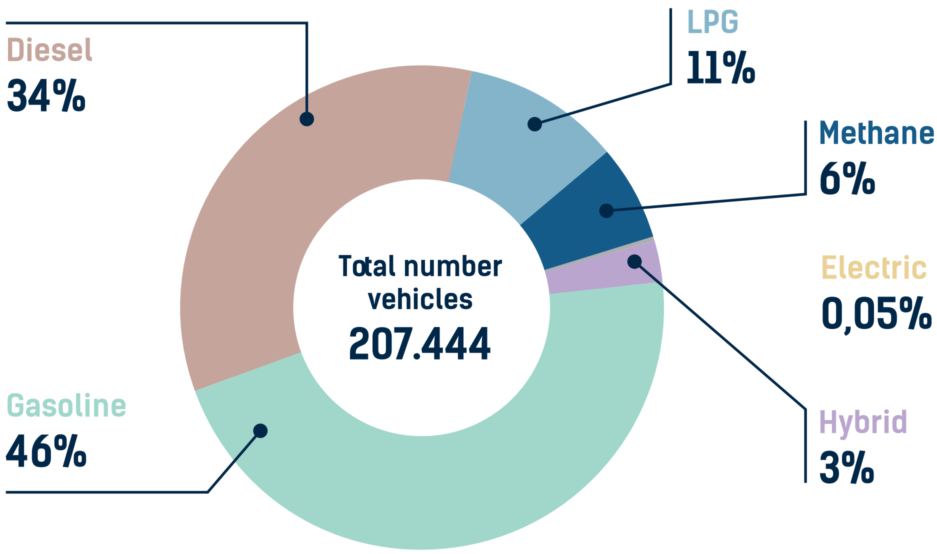
	Base Scenario		**2025 Scenario**		**2030 Scenario**	
	PM_{10}	NO_2	PM_{10}	NO_2	PM_{10}	NO_2
Number of premature deaths (N)	26	58	19	31	17	12
VSL (million euros)	107	236	77	125	71	50

Bologna

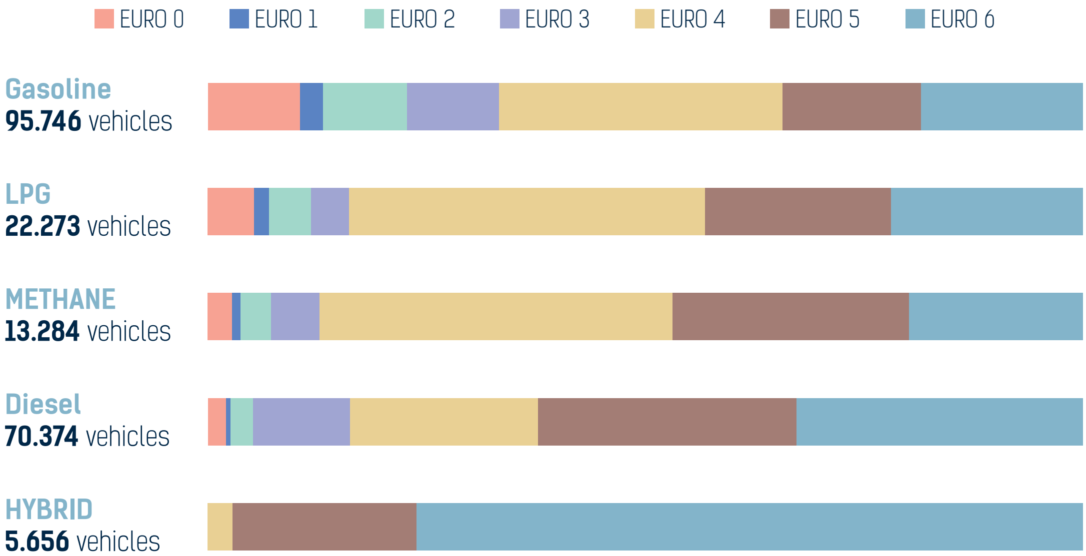
Passenger cars fleet

2018 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	26	58
VSL (million euros)	107	236

Electric Vehicles

5.656

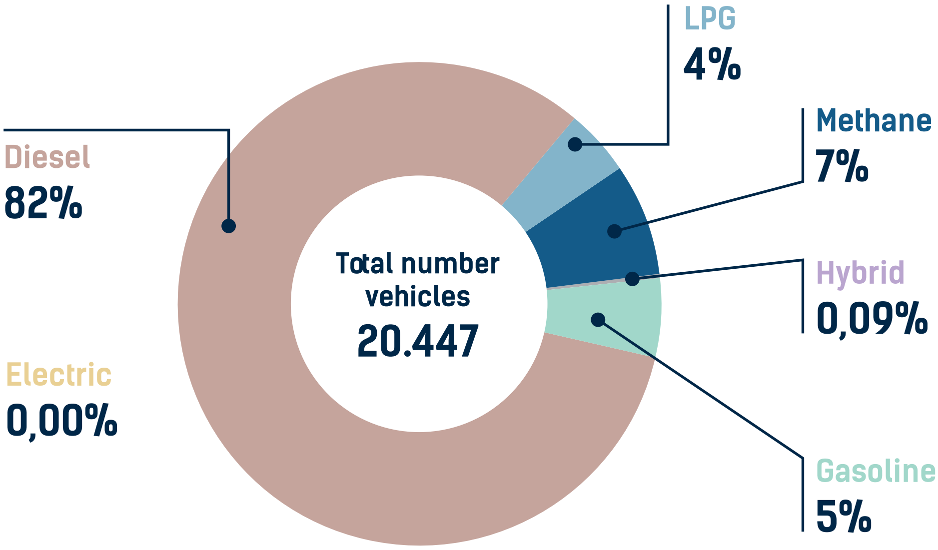
0,05% out of total number of vehicles

Bologna

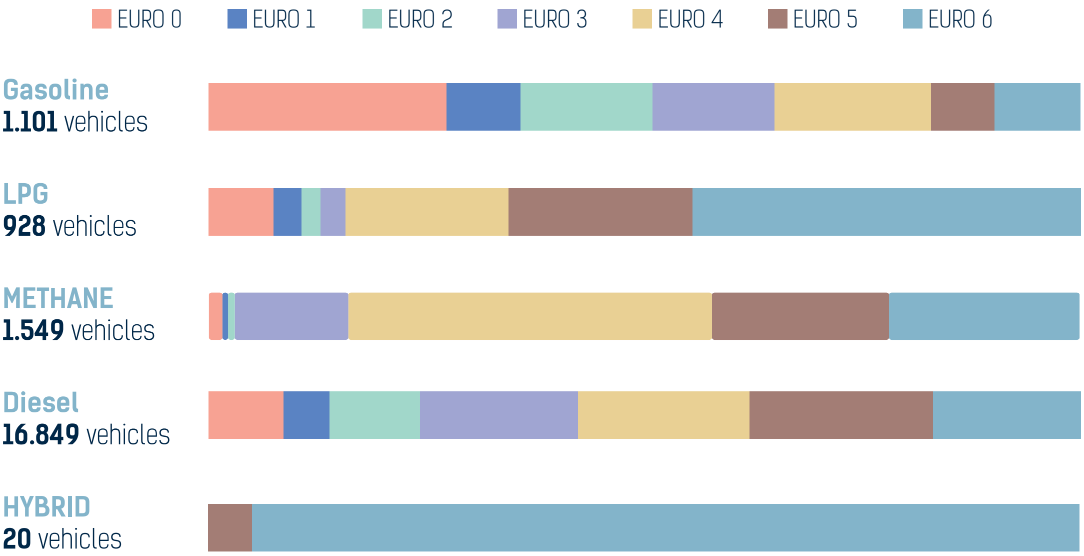
Logistics vehicle fleet

2018 Scenario

Segregation for fuel type



Segregation for Euro class



Electric Vehicles

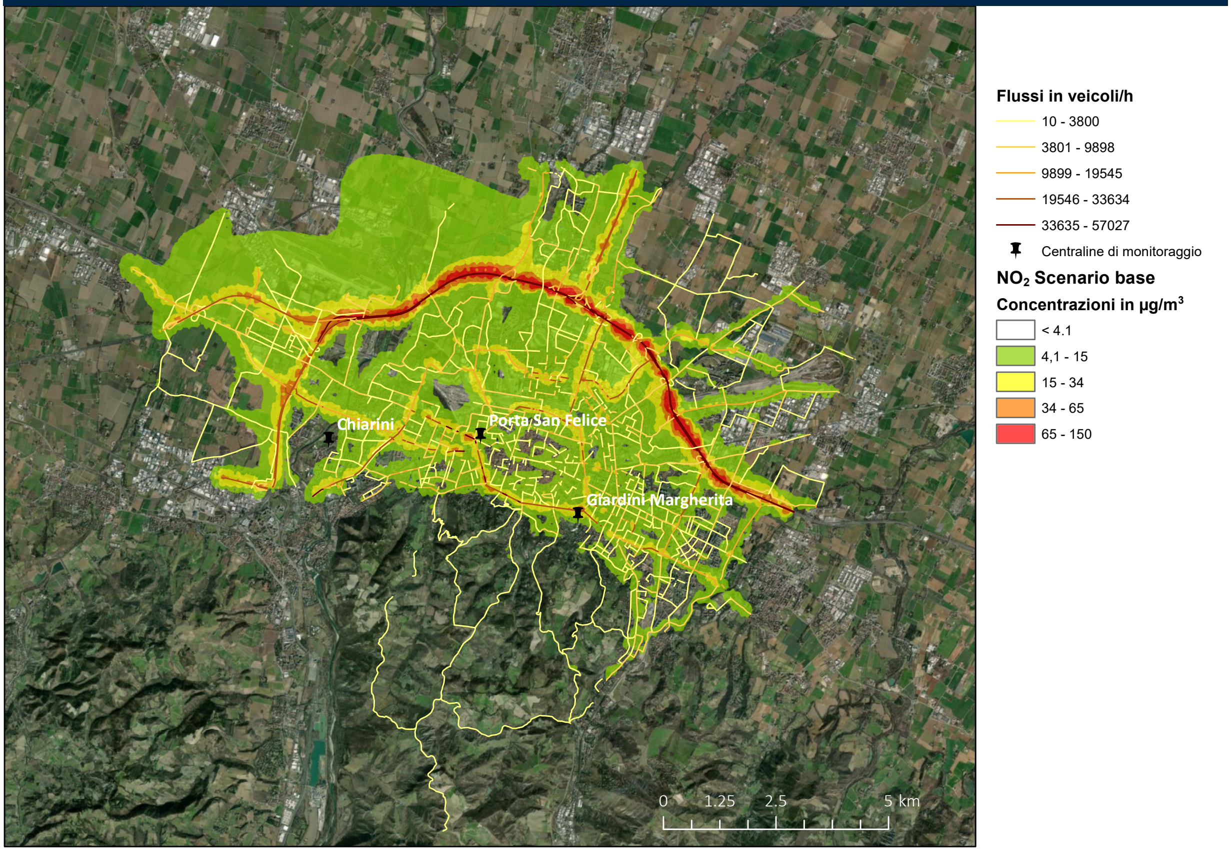
0

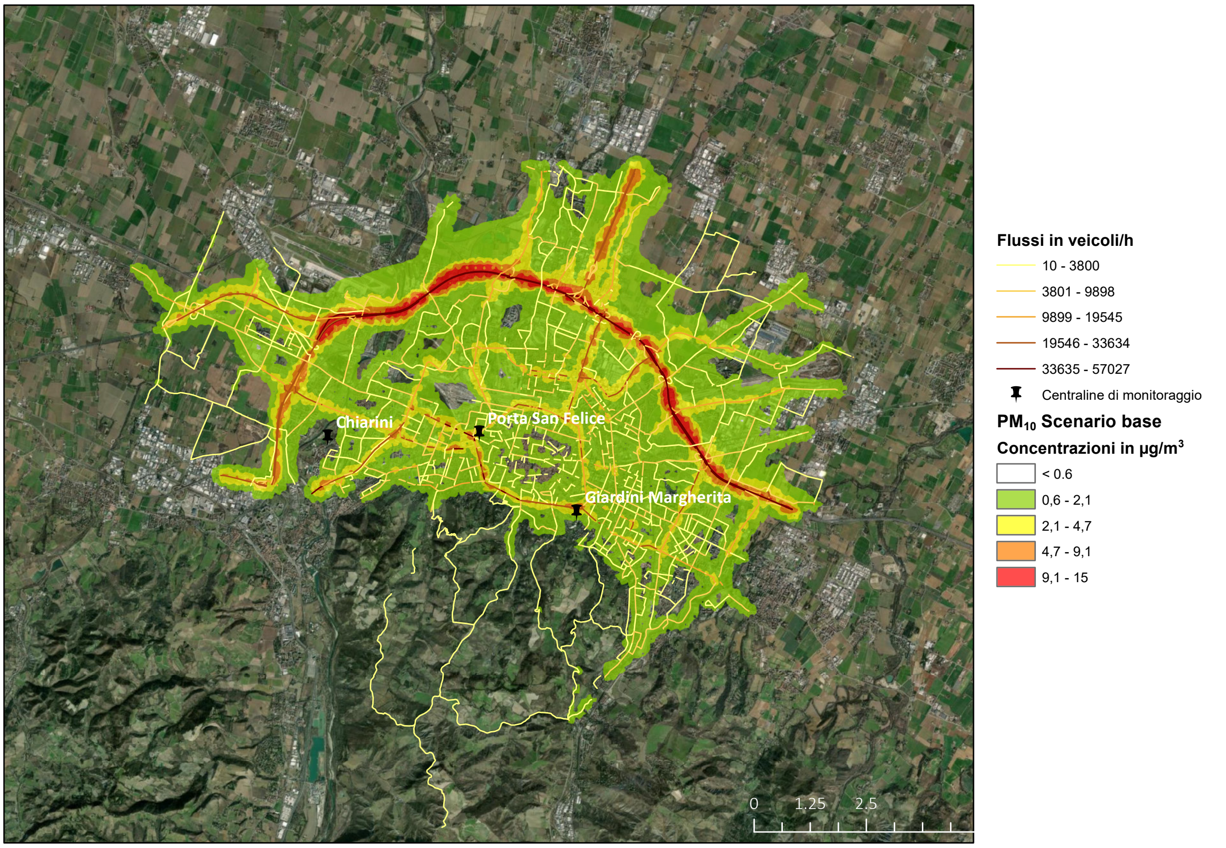
0% out of total number of vehicles

Bologna

Air quality

2018 Scenario



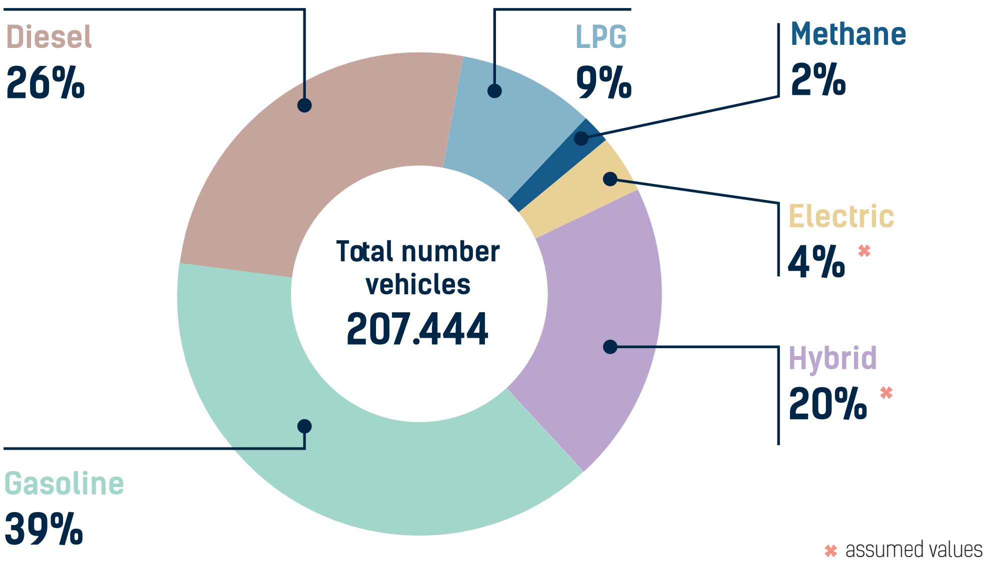


Bologna

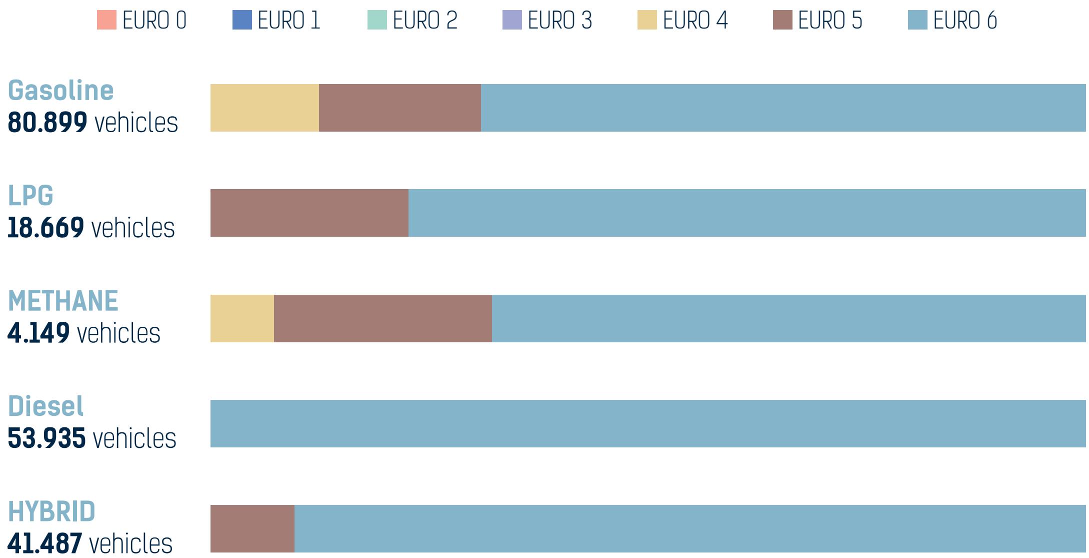
Passenger cars fleet

2025 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature de aths	19	31
VSL (million euros)	77	125

Electric Vehicles

8.298

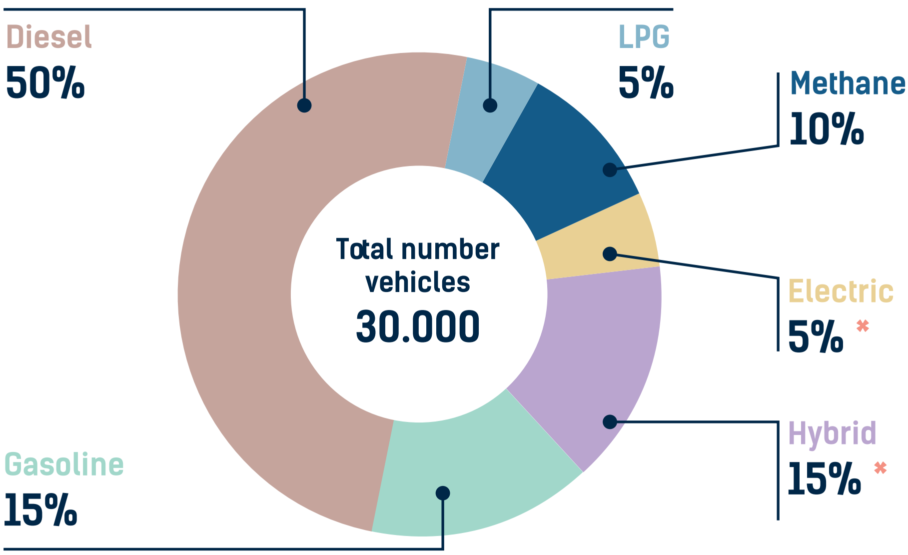
4% out of total number of vehicles

Bologna

Logistics vehicle fleet

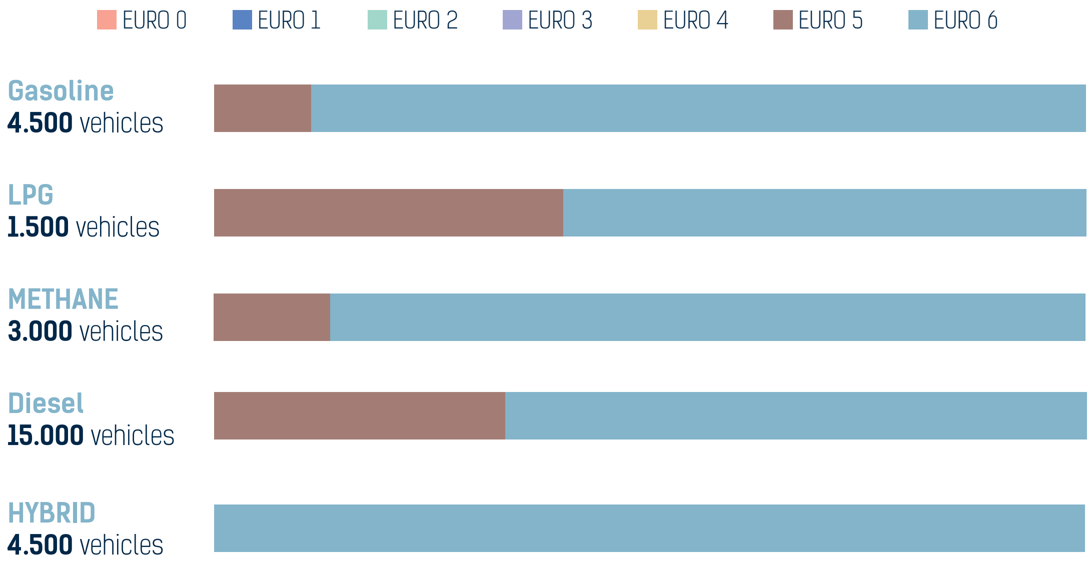
2025 Scenario

Segregation for fuel type



* assumed values

Segregation for Euro class



Electric Vehicles

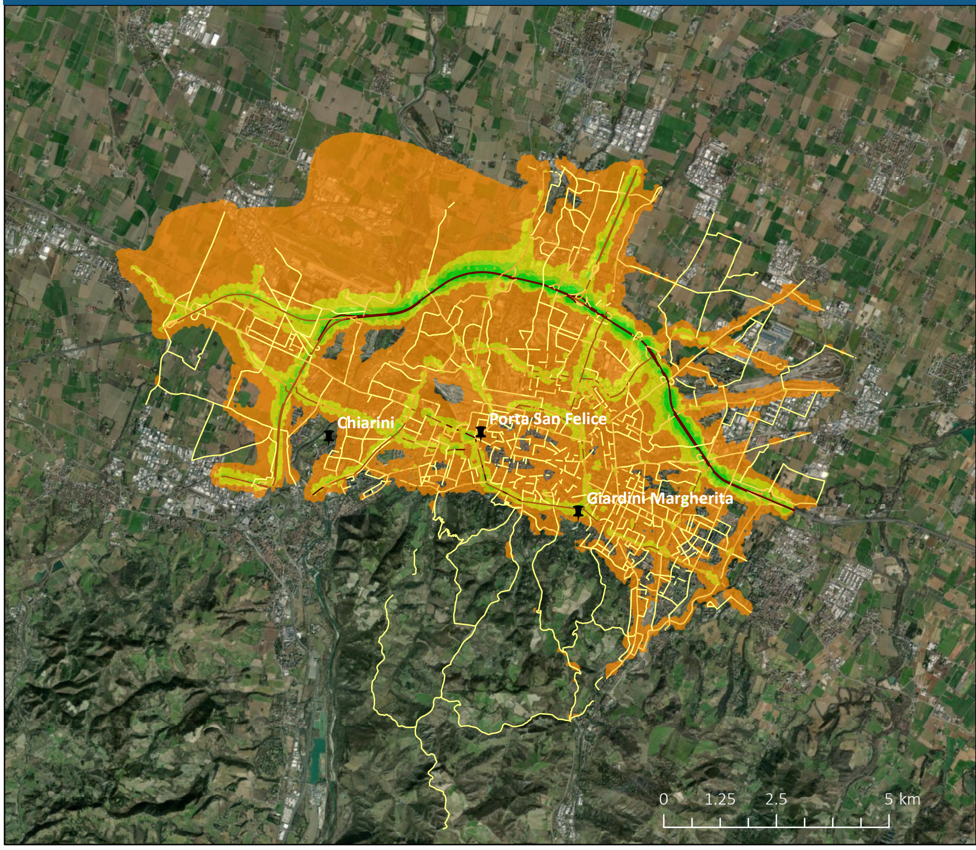
1.500

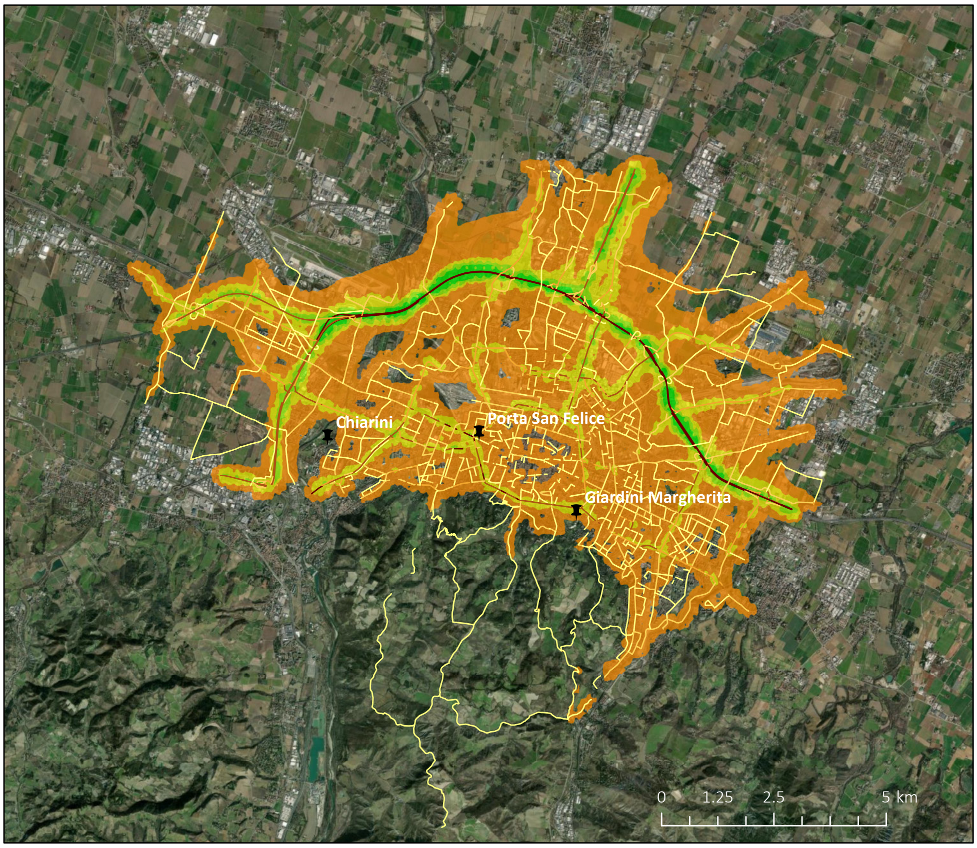
5% out of total number of vehicles

Bologna

Air quality

2025 Scenario





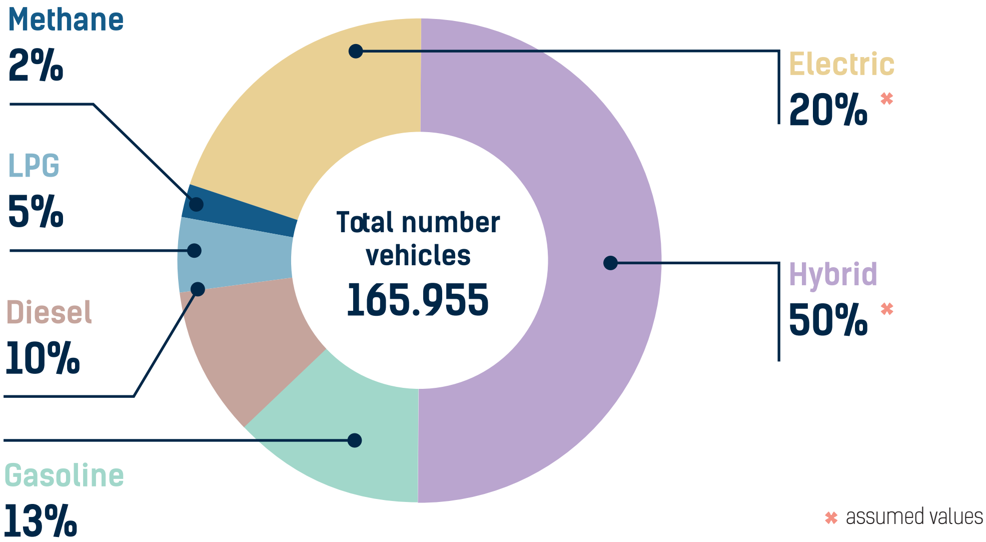
Bologna

Passenger cars fleet

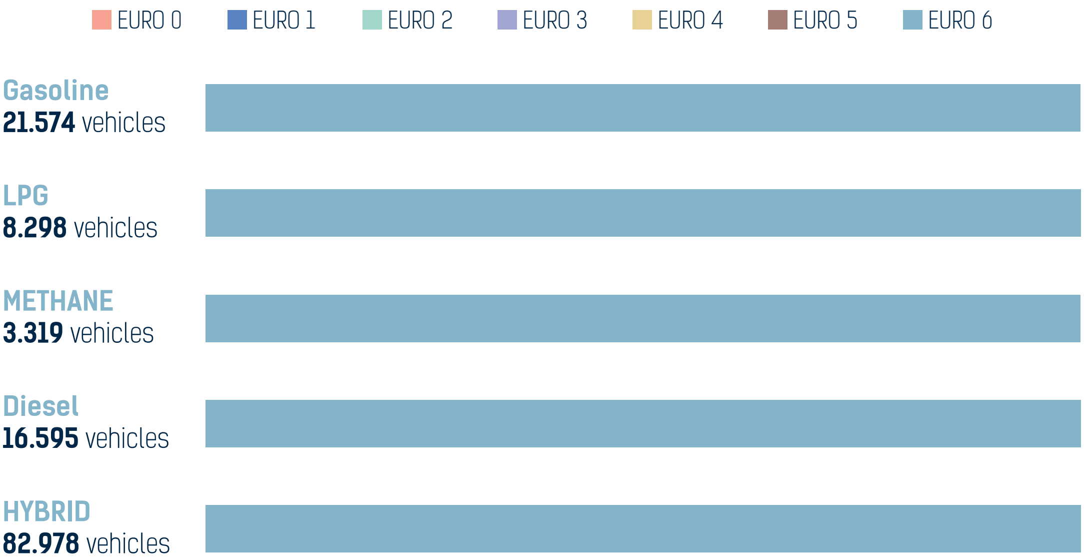
2030 Scenario

Segregation for fuel type

Total circulating fleet reduced by 20%



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	17	12
VSL (million euros)	71	50

Electric Vehicles

33.191

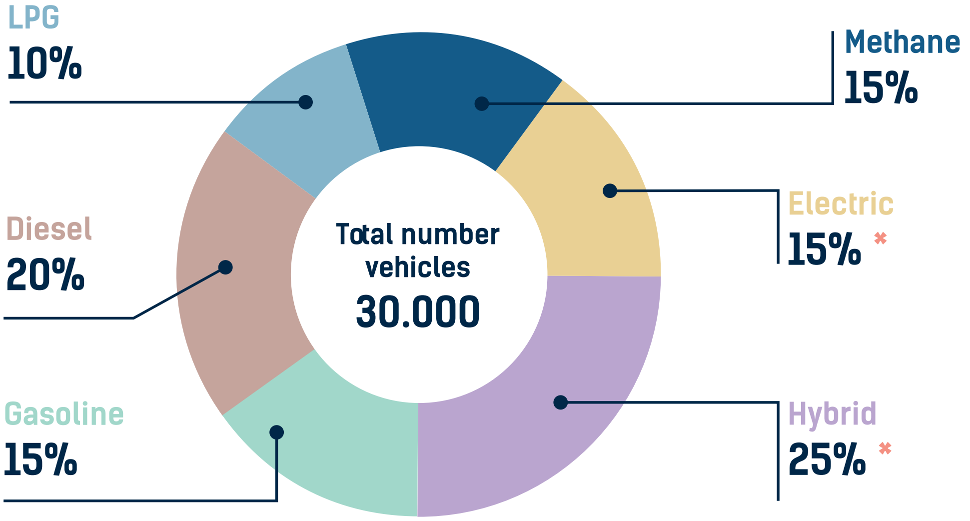
20% out of total number of vehicles

Bologna

Logistics vehicle fleet

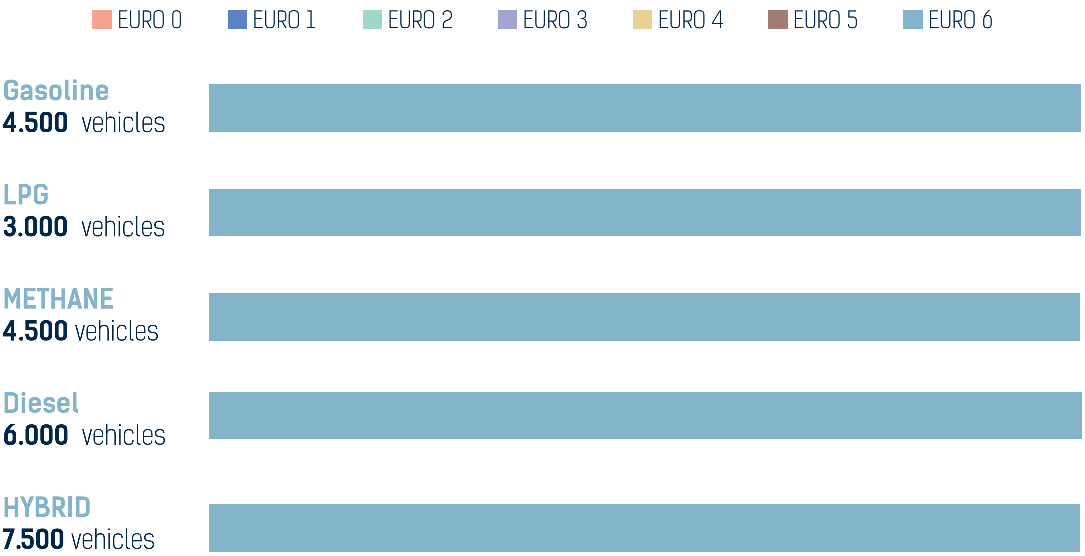
2030 Scenario

Segregation for fuel type



* assumed values

Segregation for Euro class



Electric Vehicles

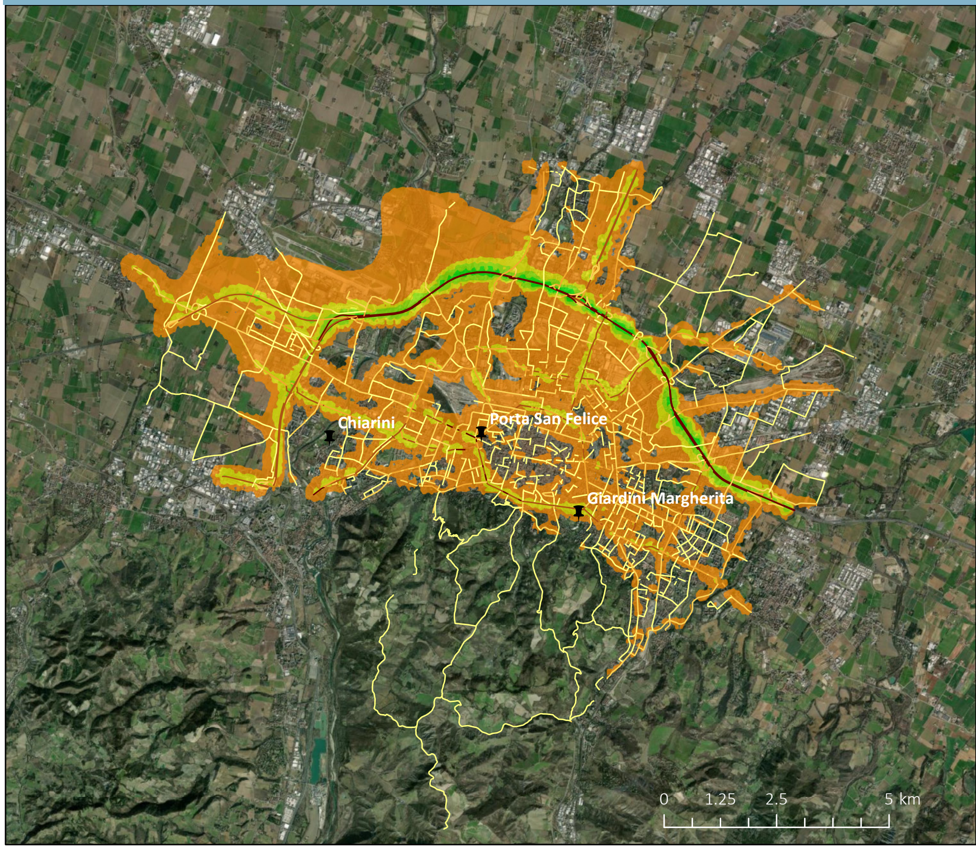
4.500

15% out of total number o
f vehicles

Bologna

Air quality

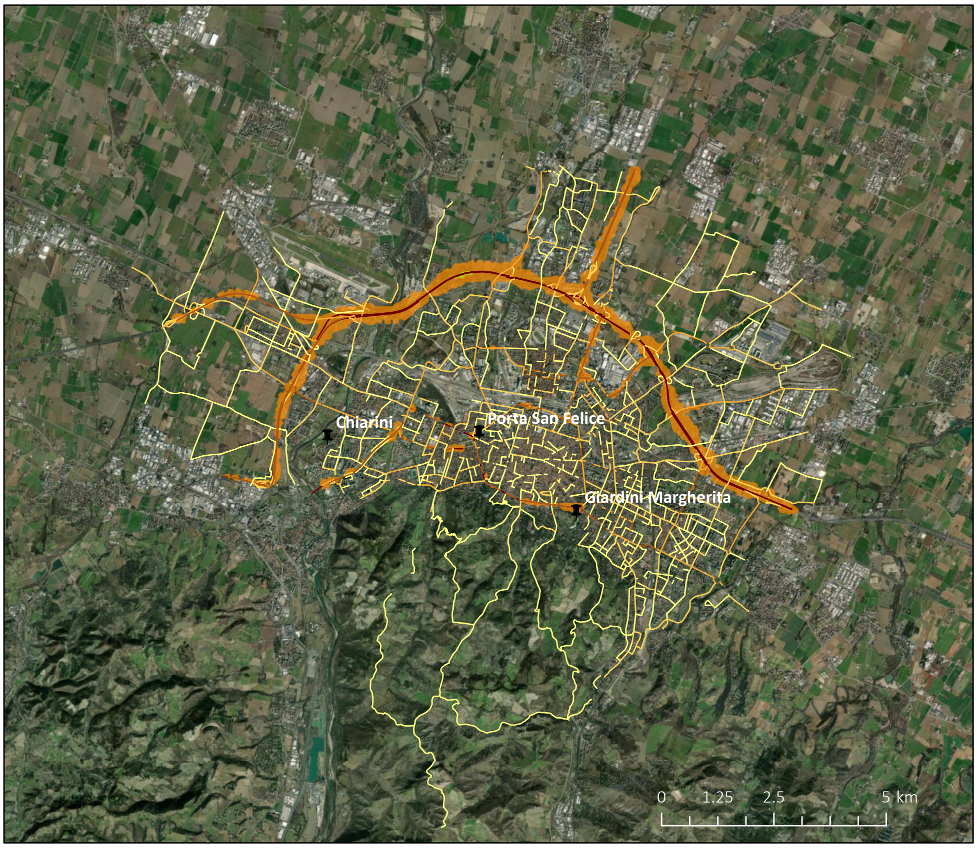
2030 Scenario



Flussi in veicoli/h
- 10 - 3800
- 3801 - 9898
- 9899 - 19545
- 19546 - 33634
- 33635 - 57027
- Centraline di monitoraggio

NO_2 2030 vs 2025

Differenza in µg/m^3
- <2
- 1,8 - 6
- 6,1 - 14
- 15 - 26
- 27 - 61



Flussi in veicoli/h
- 10 - 3800
- 3801 - 9898
- 9899 - 19545
- 19546 - 33634
- 33635 - 57027
- Centraline di monitoraggio

PM_{10} 2030 vs 2025

Differenza in µg/m^3
- < 0.2
- 0,2 - 0,65
- 0,65 - 1,5
- 1,5 - 2,9
- 2,9 - 5,9

Palermo

In this case, the vehicle fleet consists solely of the private transport sector with a prevalence of petrol (58%) and diesel (35%) vehicles and environmental class mainly Euro 0, Euro 4 and Euro 5. In the scenario to 2025 penetration of electric vehicles is expected with a percentage of 3% and of hybrid vehicles of 15%, while by 2030 a percentage of 15% has been assumed with reference to electric vehicles and 30% for hybrid vehicles.

NO_2 Concentrations

The simulated concentrations reach a maximum of about 90 µg/m^3 in the base scenario.
In future scenarios we are witnessing a net reduction, going from a percentage of 52% by 2025 to a reduction of 74% by 2030.
In terms of concentration differences, in 2025 there are reductions up to a maximum of 57 µg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030, a decrease is noted which in any case reaches a maximum of 22 µg/m^3.

PM_{10} Concentrations

From the base scenario it is clear that the PM10 values, expressed in µg/m^3, reach a maximum of about 15 µg/m^3. The areas most affected by the contribution of the vehicle fleet are those areas where the arches with the greatest traffic flows fall.
There is a reduction in concentrations, passing from the 2025 scenario to the 2030 scenario, of 38% and 46% respectively. In terms of concentration differences, in 2025 there are reductions of up to a maximum of 10 µg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030 there is an insignificant difference, between 0.27 and 1 µg/m^3.

Health and economic impact

Using the simulated concentration values, only in the traffic control units at rush hour (8 am) in the winter period (January), with ADMS-Roads and implementing the data in the BenMap software for each pollutant analyzed, PM_{10} and NO_2 and for each hypothesized scenario, the number of premature deaths due to the short-term effects relating only to the transport sector was estimated and the related associated cost was estimated.

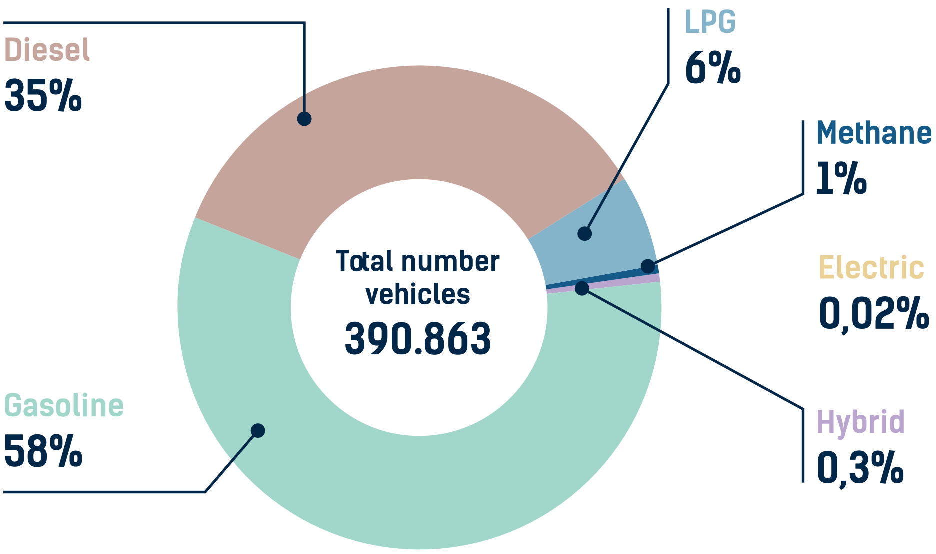
	Base Scenario		2025 Scenario		2030 Scenario	
	PM_{10}	NO_2	PM_{10}	NO_2	PM_{10}	NO_2
Number of premature deaths (N)	39	94	24	45	21	25
VSL (million euros)	73	177	45	85	40	46

Palermo

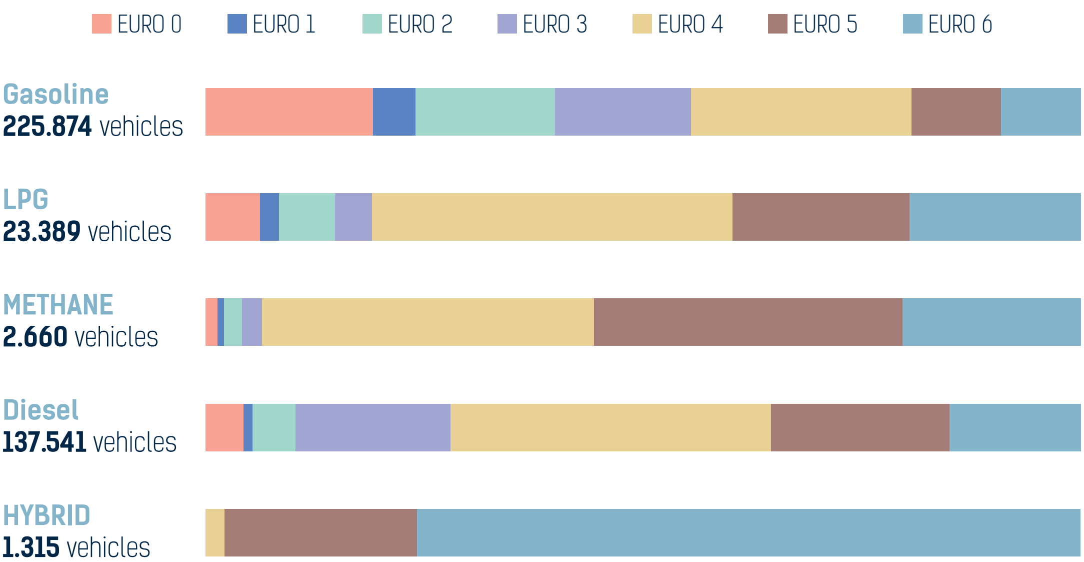
Passenger cars fleet

2018 Scenario

Segregation for fuel type



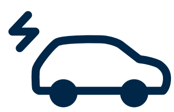
Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	39	94
VSL (million euros)	73	177

Electric Vehicles



84

0,02% out of total number of vehicles

Palermo

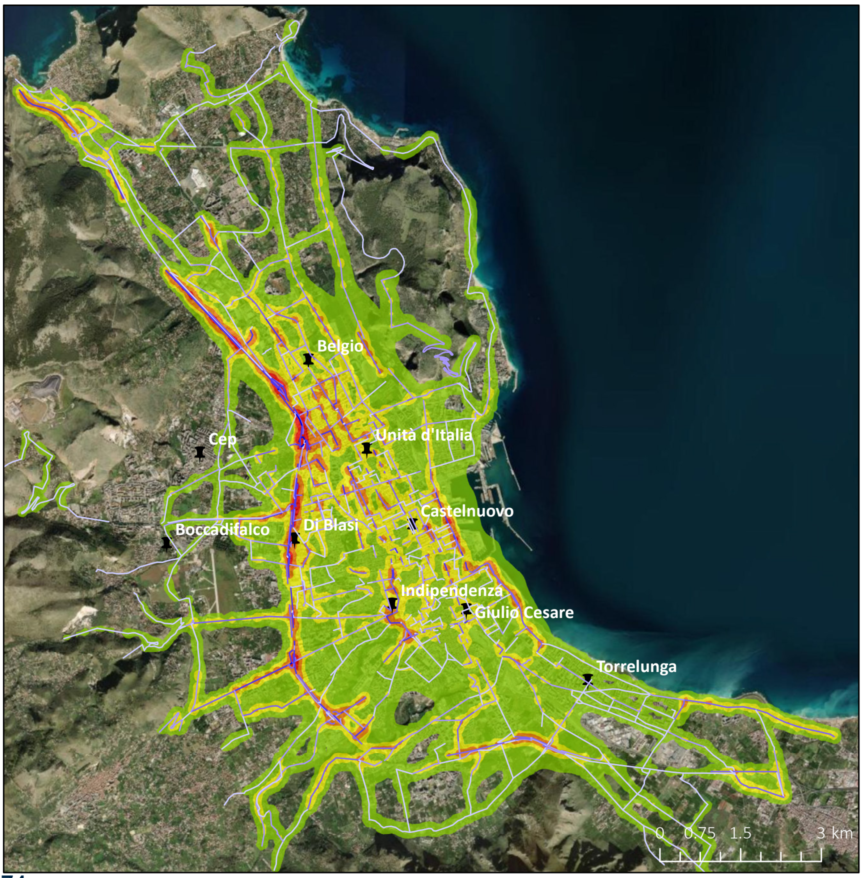
Air quality

2018 Scenario

Flussi veicoli/h
- 1 - 448
- 449 - 1038
- 1039 - 1861
- 1862 - 3439
- 3440 - 5590
- Centraline di monitoraggio

NO_2 Scenario base

Concentrazione in µg/m^3
- < 5
- 5 - 15
- 15 - 25
- 25 - 35
- 35 - 80



Flussi veicoli/h
- 1 - 448
- 449 - 1038
- 1039 - 1861
- 1862 - 3439
- 3440 - 5590
- Centraline di monitoraggio

PM_{10} Scenario base

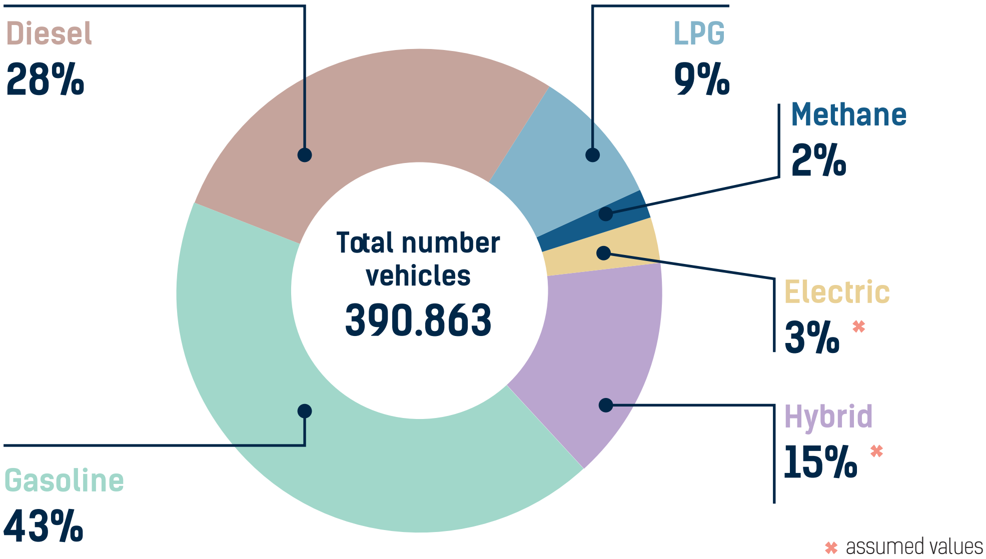
Concentrazione in µg/m^3
- < 0,5
- 0,5 - 1,5
- 1,5 - 3
- 3 - 6
- 6 - 15

Palermo

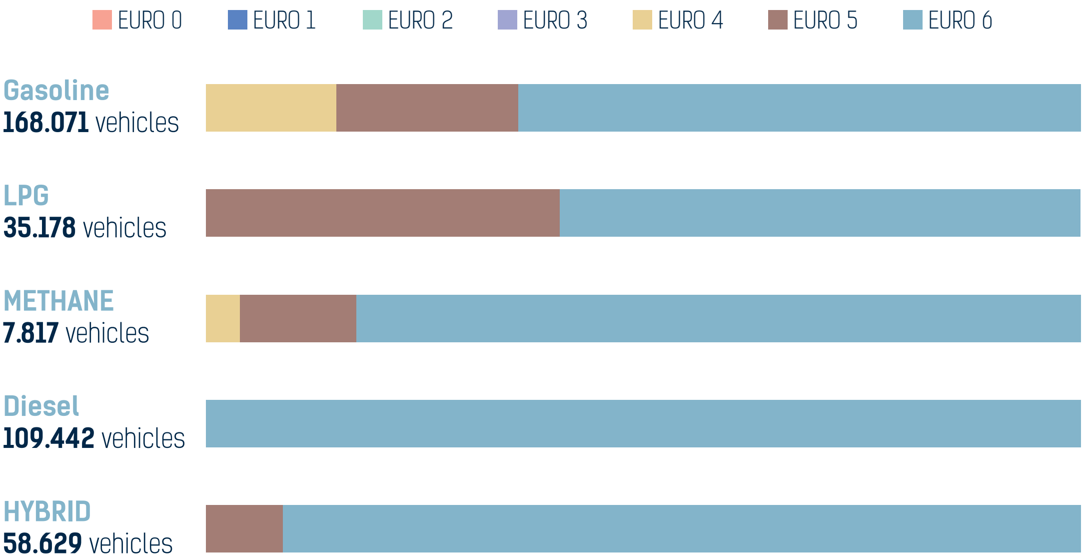
Passenger cars fleet

2025 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature de aths	24	45
VSL (million euros)	45	85

Electric Vehicles

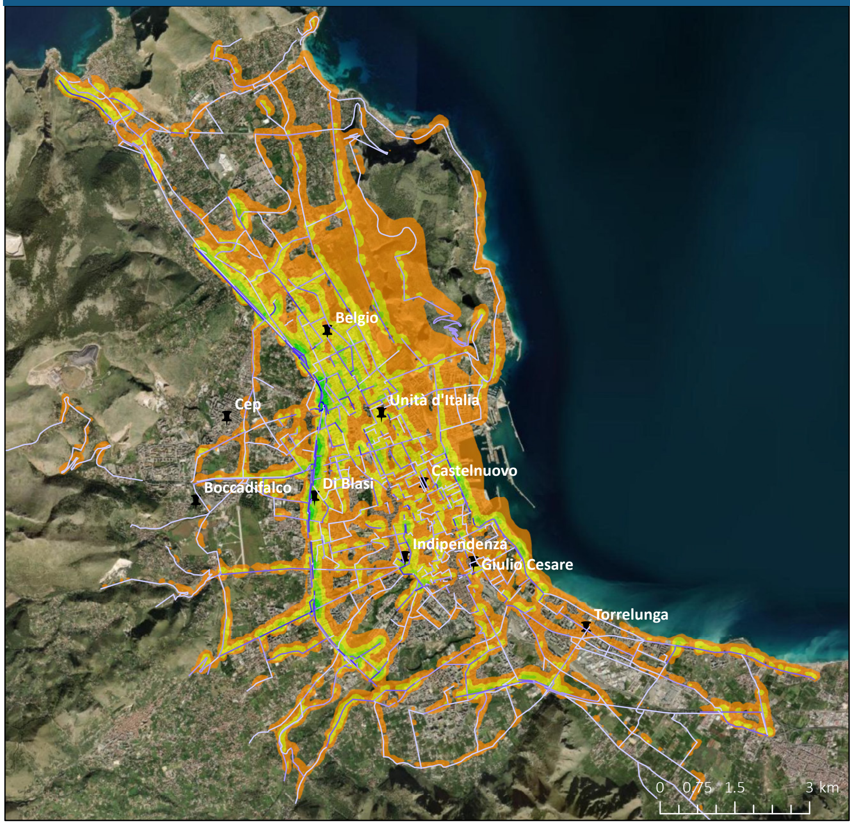
11.726

3% out of total number of vehicles

Palermo

Air quality

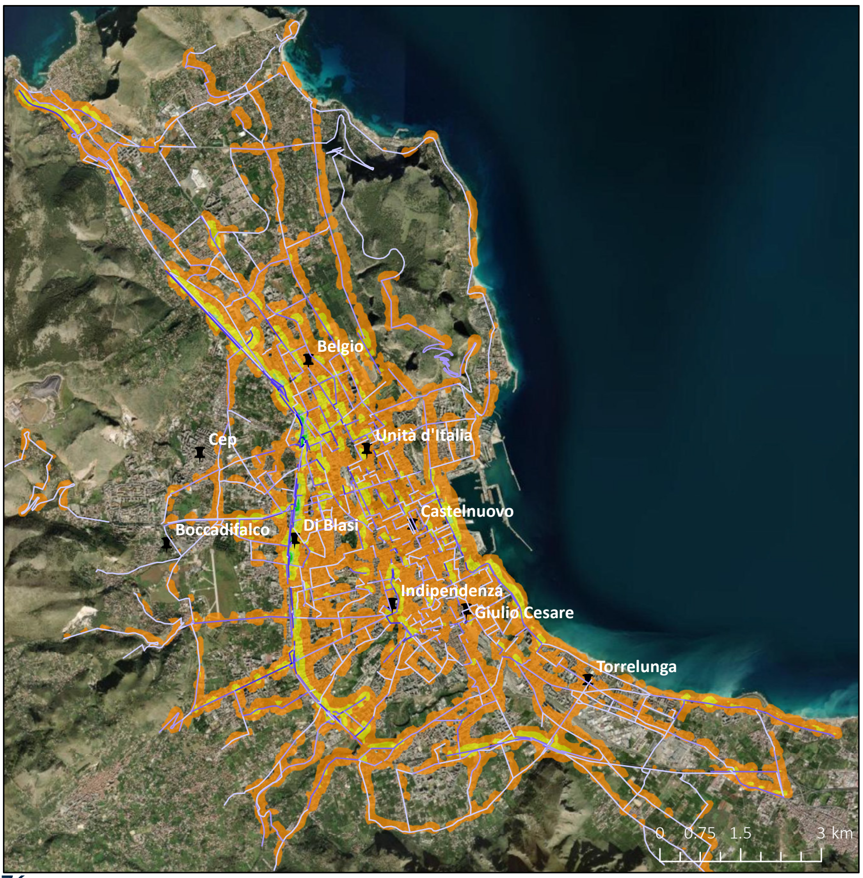
2025 Scenario



Flussi veicoli/h
- 1 - 448
- 449 - 1038
- 1039 - 1861
- 1862 - 3439
- 3440 - 5590
- Centraline di monitoraggio

NO_2 2025 vs base

Differenza in µg/m³
- < 2
- 2 - 5
- 5 - 15
- 15 - 30
- 30 - 45



Flussi veicoli/h
- 1 - 448
- 449 - 1038
- 1039 - 1861
- 1862 - 3439
- 3440 - 5590
- Centraline di monitoraggio

PM_{10} 2025 vs base

Differenza in µg/m³
- < 0,5
- 0,5 - 1,5
- 1,5 - 4
- 4 - 6
- 6 - 10

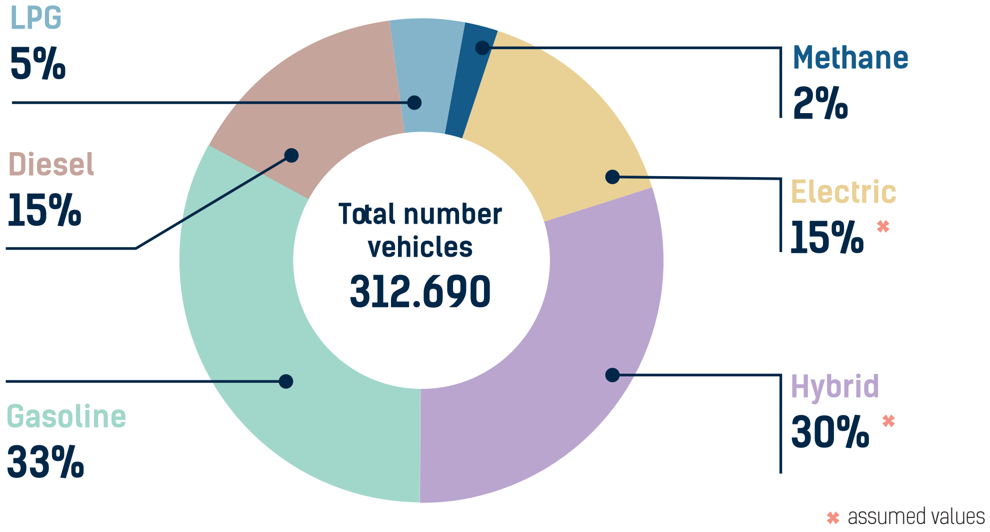
Palermo

Passenger cars fleet

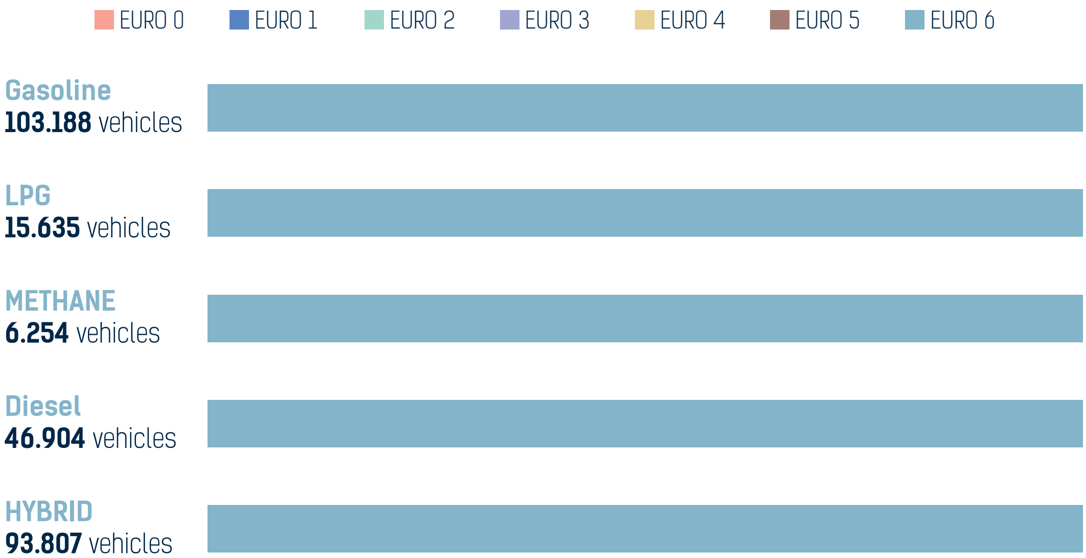
2030 Scenario

Segregation for fuel type

Total circulating fleet reduced by 20%



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature deaths	21	25
VSL (million euros)	40	46

Electric Vehicles

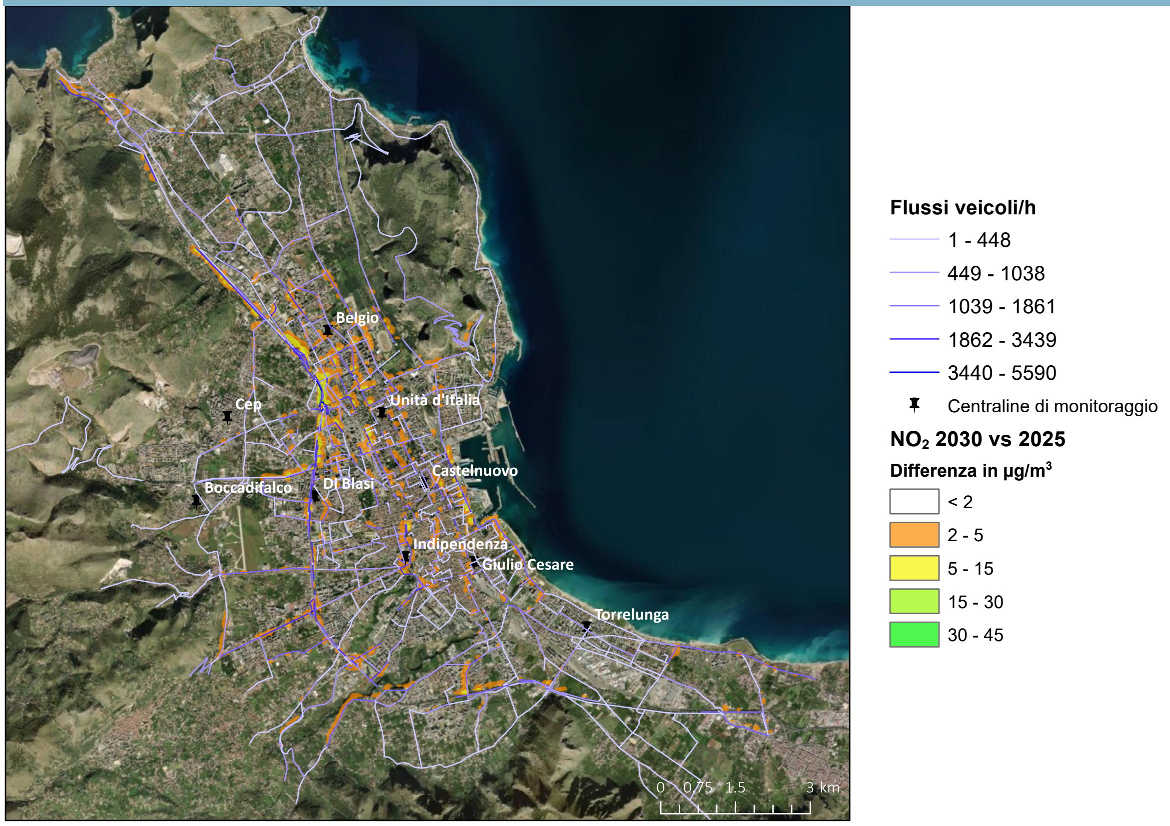
46.904

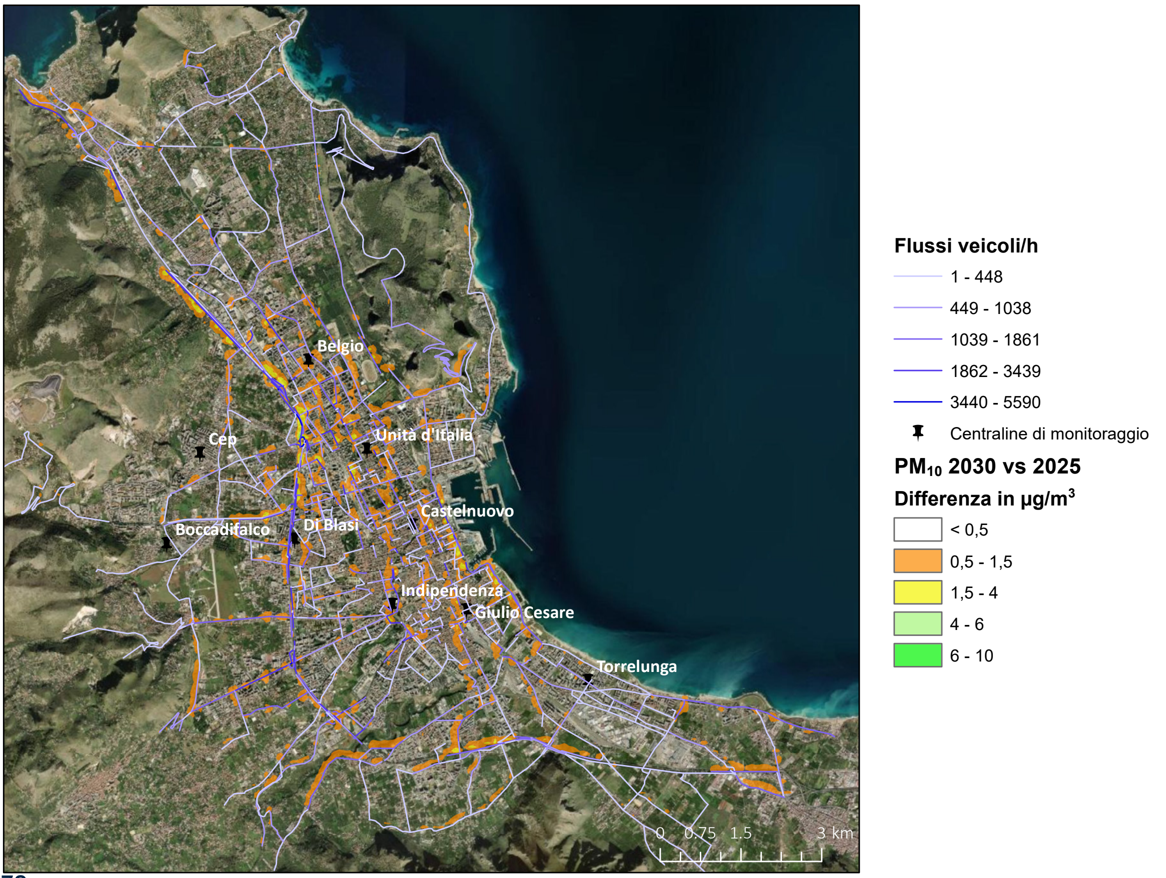
15% out of total number of vehicles

Palermo

Air quality

2030 Scenario





Milan

The vehicle fleet analyzed consists only of the private transport sector, with a prevalence of petrol (58%) and diesel (34%) vehicles and environmental class mainly Euro 4, Euro 5 and Euro 6. In the scenario to 2025, a penetration of electric vehicles with a percentage equal to 4% and hybrid vehicles of 20%, while in 2030 a percentage of 20% was assumed with reference to electric vehicles and 50% for hybrid vehicles.

NO_2 Concentrations

The average hourly concentrations simulated on a winter weekday in January reach a maximum of about 140 μg/m^3 in the base scenario. The vehicle fleet consists, in this case, of the private transport sector only.
In future scenarios we are witnessing a clear reduction in concentrations from a percentage of 62% by 2025 up to a reduction of 84% by 2030. In terms of concentration differences, by 2025 there are reductions of up to a maximum of 68 μg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030, a decrease is noted which in any case reaches a maximum of 45 μg/m^3.

PM_{10} Concentrations

The average daily values of PM10 reach a maximum of about 21 μg/m^3 for the basic scenario referring to a winter working day in January. The areas most affected by the contribution of the vehicle fleet are linked to the areas in which the arches with the greatest traffic flows fall.
There is a reduction in concentrations, passing from the 2025 scenario to the 2030 scenario, of 36% and 41% respectively. In terms of concentration differences, in 2025 there are reductions of up to a maximum of 14 μg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030 there is a not very significant difference, less than 0.45 μg/m^3.

Health and economic impact

Using the simulated concentration values, only in the traffic control units at rush hour (8 am) in the winter period (January), with ADMS-Roads and implementing the data in the BenMap software for each pollutant analyzed, PM_{10} and NO_2 and for each hypothesized scenario, the number of premature deaths due to short-term effects relating only to the transport sector was estimated and the related associated cost was estimated.

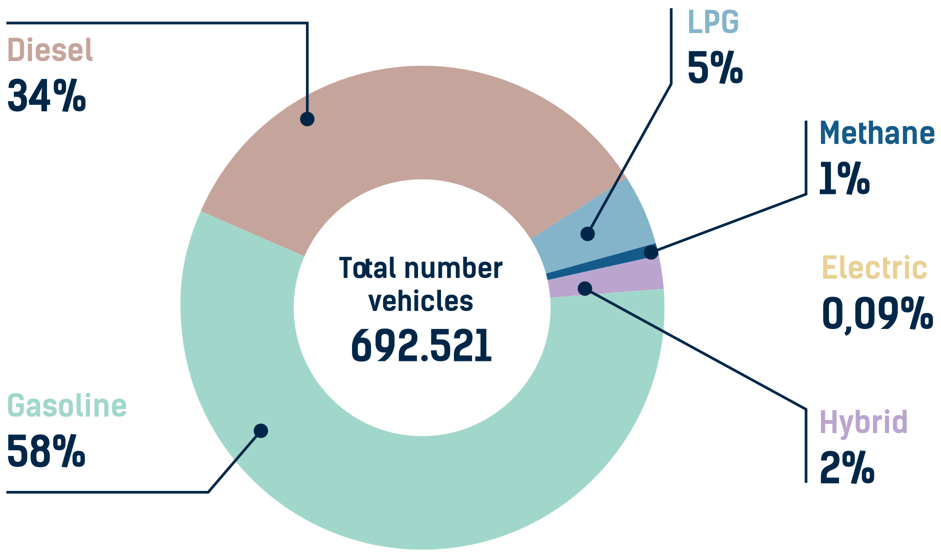
	Base Scenario		2025 Scenario		2030 Scenario	
	PM_{10}	NO_2	PM_{10}	NO_2	PM_{10}	NO_2
Number of premature deaths (N)	269	639	173	244	159	103
VSL (million euros)	1195	2834	766	1083	706	45

Milan

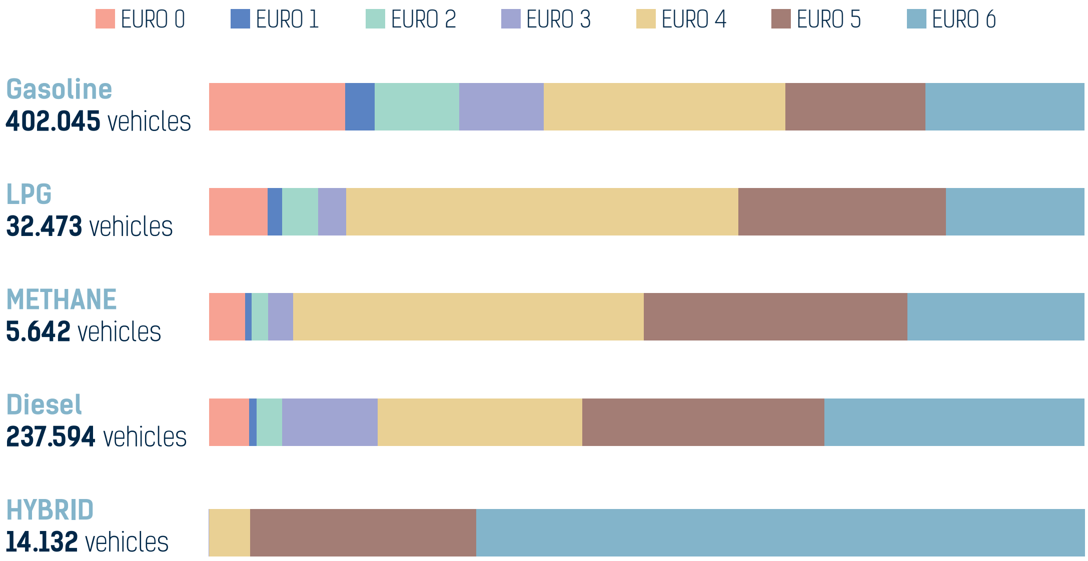
Passenger cars fleet

2018 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature deaths	269	639
VSL (million euros)	1.195	2.834

Electric Vehicles

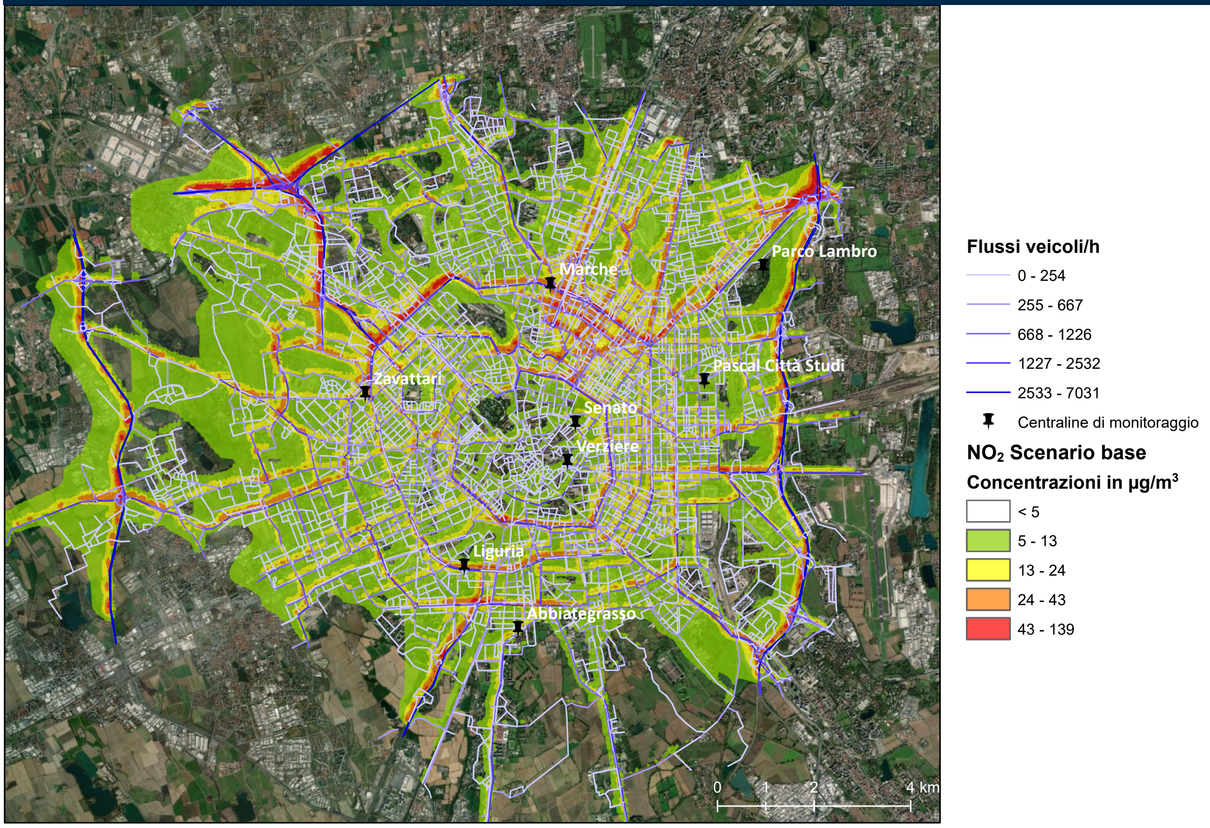
635

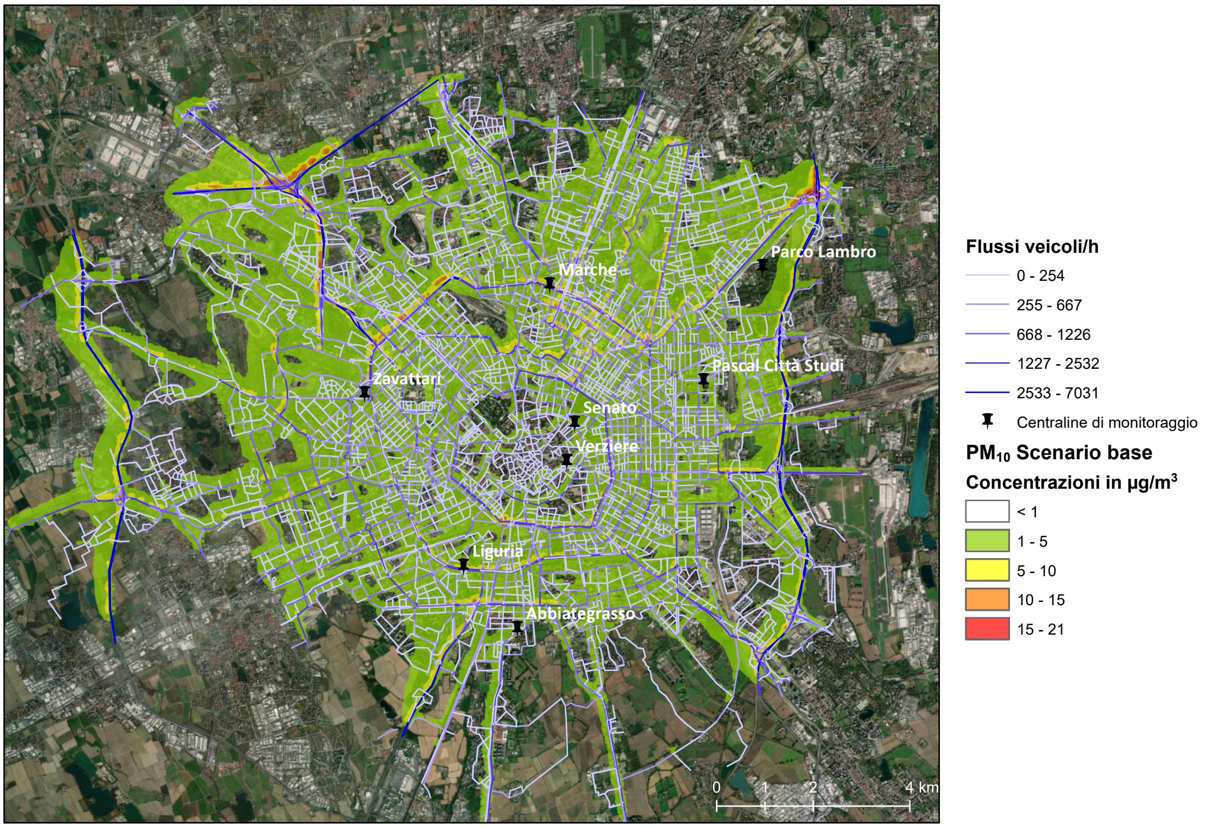
0,09% out of total number of vehicles

Milan

Air quality

2018 Scenario



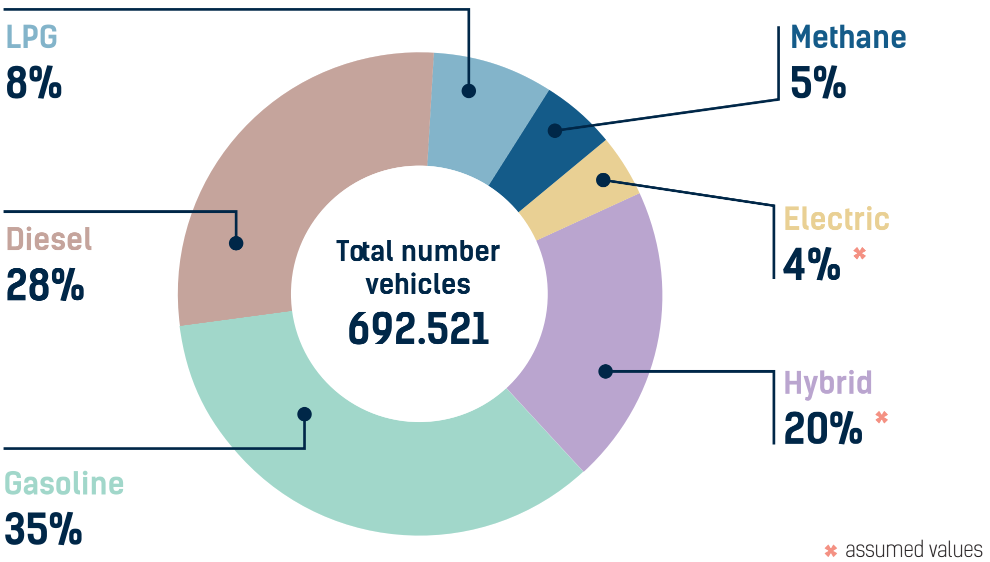


Milan

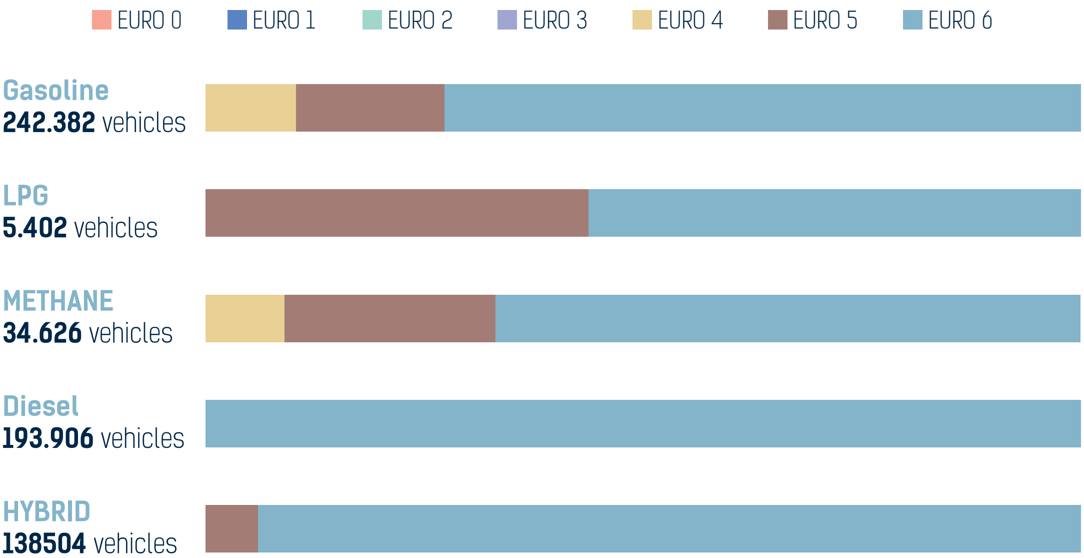
Passenger cars fleet

2025 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature de aths	173	244
VSL (million euros)	766	1.083

Electric Vehicles

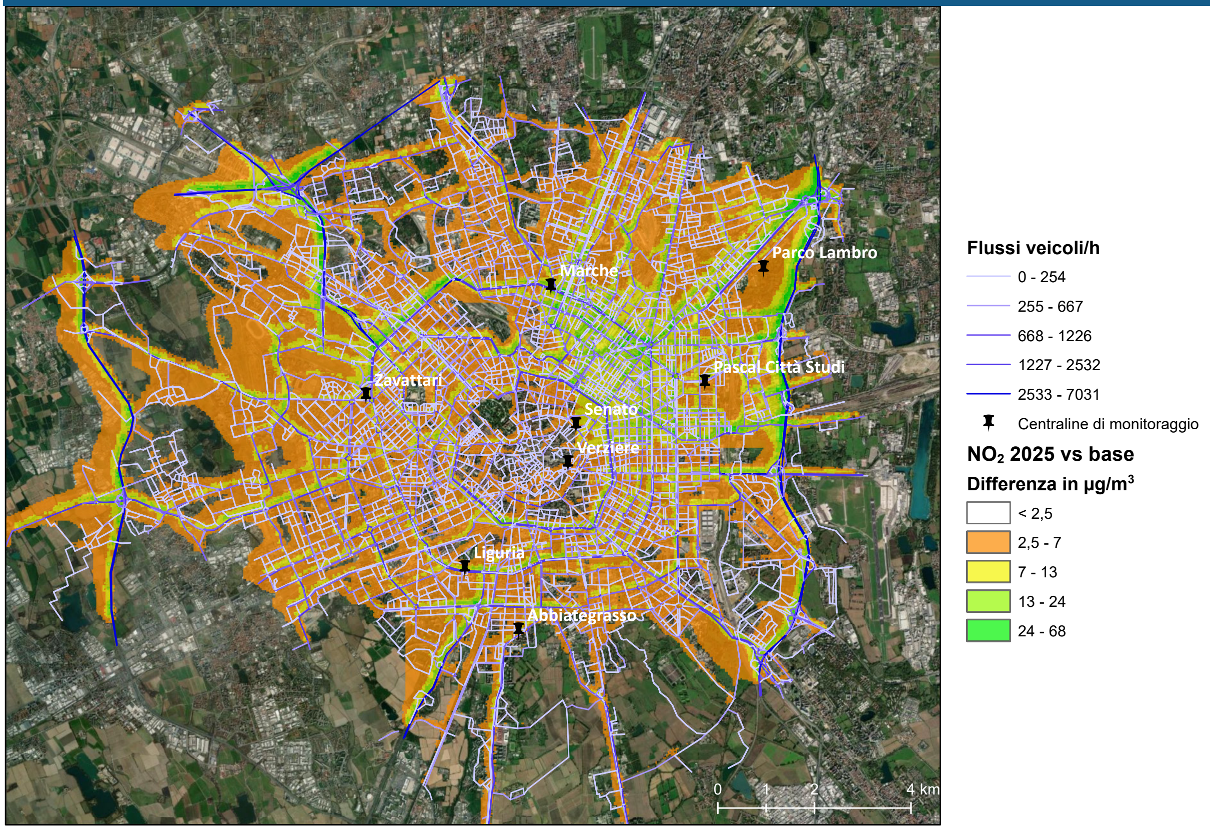
27.701

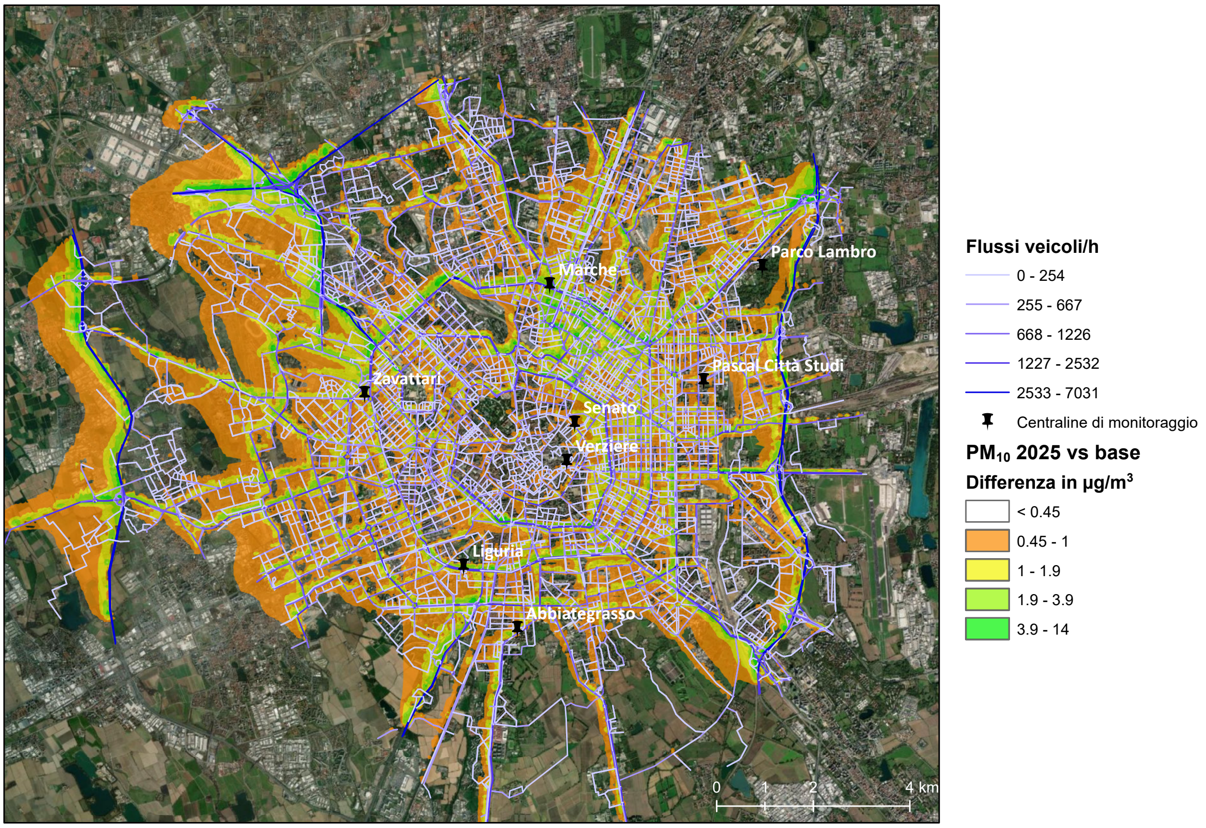
4% out of total number of vehicles

Milan

Air quality

2025 Scenario





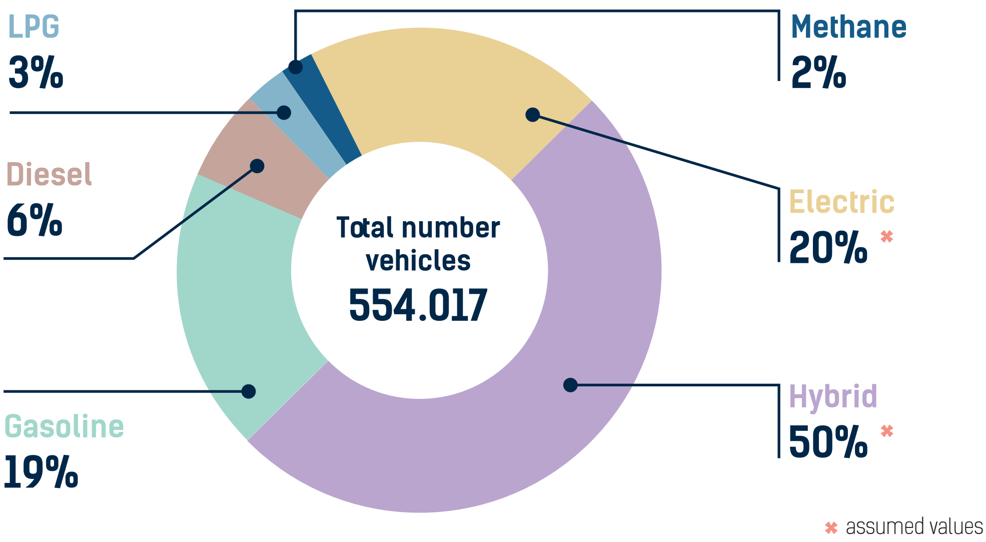
Milan

Passenger cars fleet

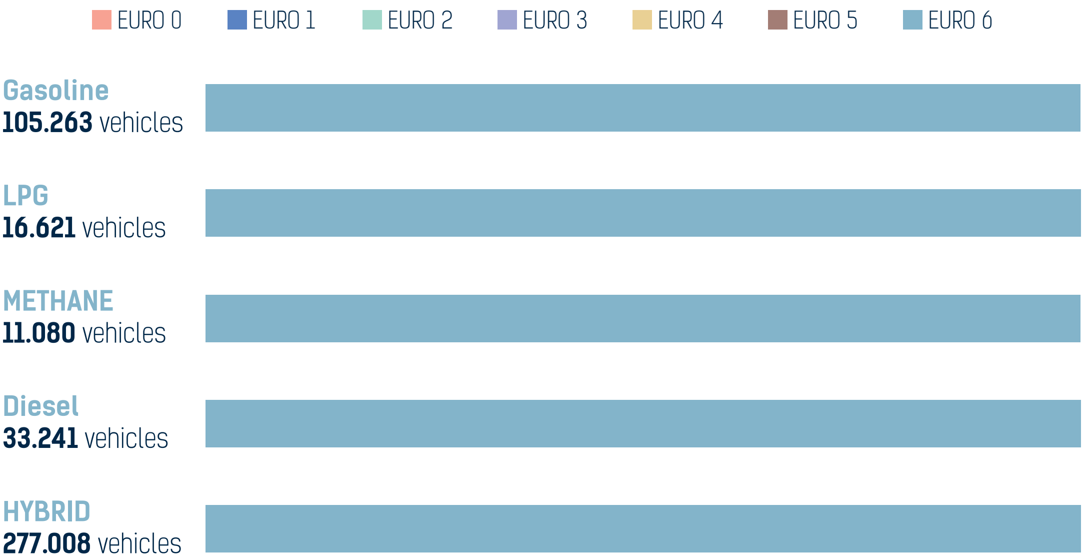
2030 Scenario

Segregation for fuel type

Total circulating fleet reduced by 20%



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	159	103
VSL (million euros)	706	45

Electric Vehicles

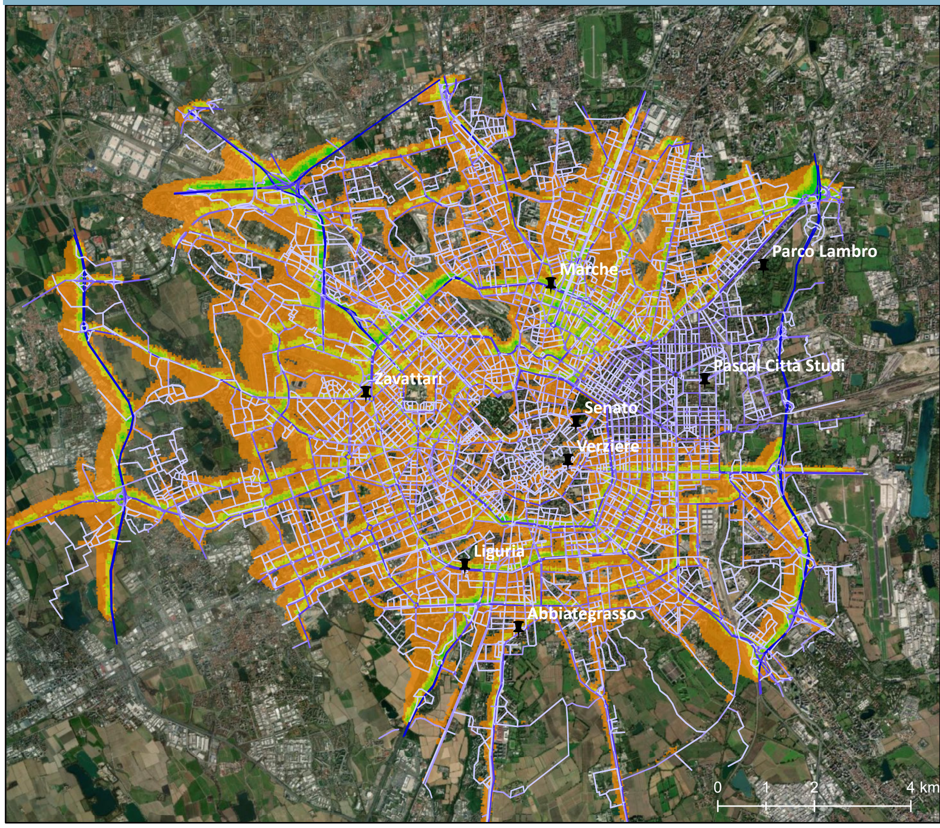
110.803

20% out of total number of vehicles

Milan

Air quality

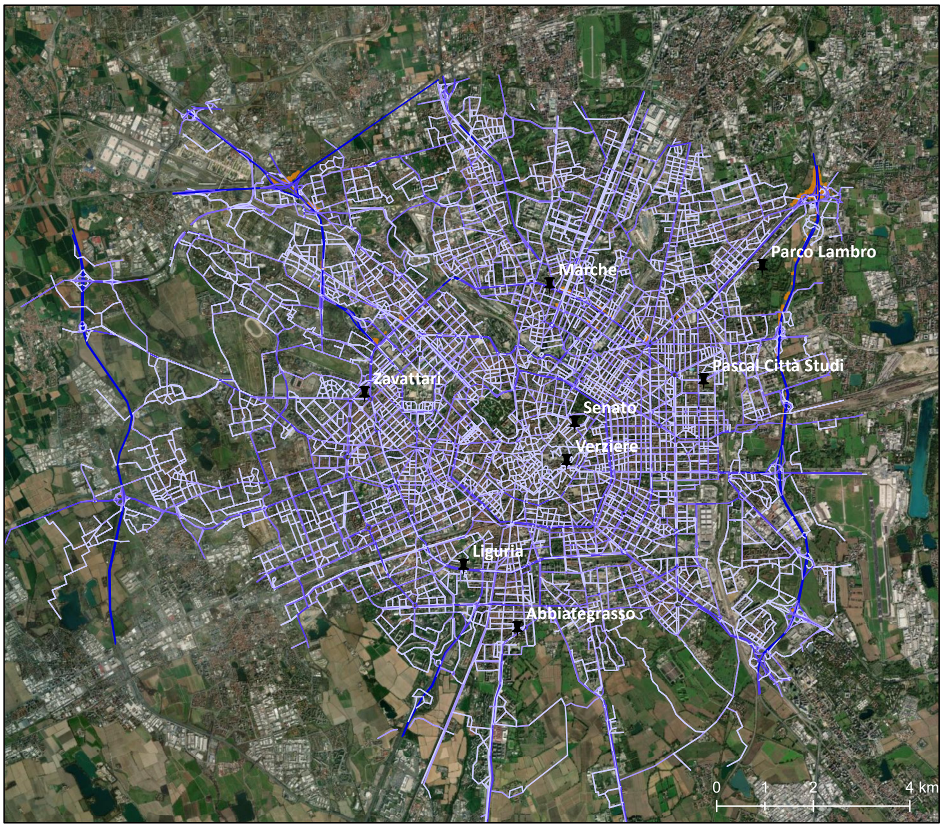
2030 Scenario



Flussi veicoli/h
- 0 - 254
- 255 - 667
- 668 - 1226
- 1227 - 2532
- 2533 - 7031
- Centraline di monitoraggio

NO_2 2030 vs 2025

Differenza in µg/m^3
- < 2,5
- 2,5 - 7
- 7 - 13
- 13 - 24
- 24 - 68



Flussi veicoli/h
- 0 - 254
- 255 - 667
- 668 - 1226
- 1227 - 2532
- 2533 - 7031
- Centraline di monitoraggio

PM_{10} 2030 vs 2025

Differenza in µg/m^3
- < 0.45
- 0.45 - 1
- 1 - 1.9
- 1.9 - 3.9
- 3.9 - 14

Rome

The vehicle fleet analyzed consists, in this case, of the private transport sector only. In the base scenario, the vehicle fleet is mainly made up of petrol and diesel vehicles with percentages of 53% and 38% respectively. The most common environmental classes are those Euro 4, Euro 5 and Euro 6. In the 2025 scenario, a penetration of electric vehicles is expected with a percentage equal to 4% and hybrid vehicles of 20%, while by 2030 a percentage is assumed 20% for electric vehicles and 50% for hybrid vehicles.

NO_2 Concentrations

The simulated hourly average concentrations reach a maximum of about 50 μg/m^3 in the base scenario. In future scenarios we obtained a net reduction in the average hourly concentrations of NO2 due to the private transport sector alone, which goes from a percentage of 53% by 2025 to a reduction of 89% by 2030. In terms of concentration differences, by 2025 there are reductions of up to a maximum of 39 μg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030, a constant decrease is noted which in any case reaches a maximum of 20 μg/m^3.

PM_{10} Concentrations

In the base scenario, the daily PM10 concentration values due to private transport reach a maximum of about 22 μg/m^3. The areas most affected by the contribution of the private vehicle fleet are concentrated in the arches with the greatest traffic flows, in this case coinciding with the GRA.
In future scenarios we are witnessing a net reduction, going from a percentage of 36% by 2025 to a not very significant reduction of 42% by 2030. In terms of concentration differences, by 2025 there are reductions up to a maximum of 9 μg/m^3 compared to the base scenario, while comparing the scenario in 2025 with the scenario in 2030, there is an insignificant difference, less than 1.8 μg/m^3.

Health and economic impact

Using the simulated concentration values, only in the traffic control units at rush hour (8 am) in the winter period (January), with ADMS-Roads and implementing the data in the BenMap software for each pollutant analyzed, PM_{10} and NO_2 and for each hypothesized scenario, the number of premature deaths due to short-term effects relating only to the transport sector was estimated and the related associated cost was estimated.

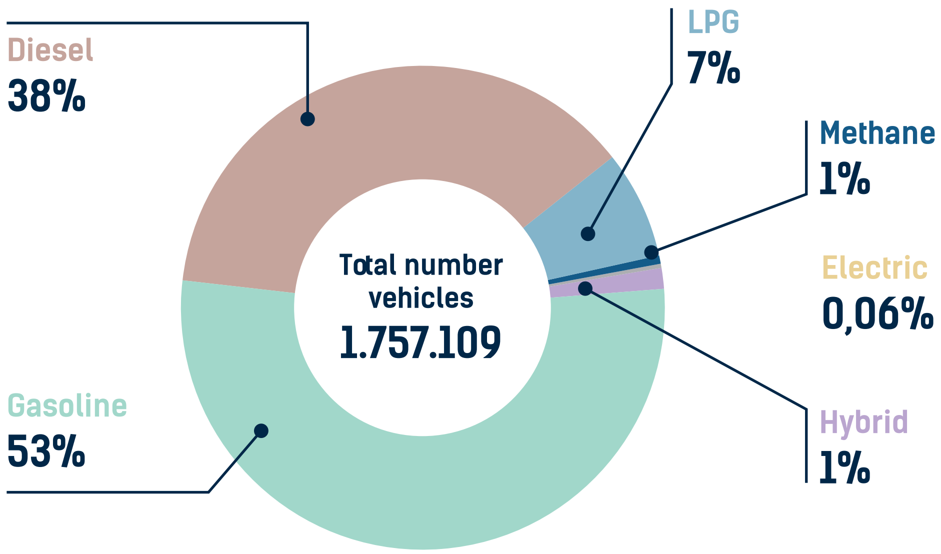
	Base Scenario		2025 Scenario		2030 Scenario	
	PM_{10}	NO_2	PM_{10}	NO_2	PM_{10}	NO_2
Number of premature deaths (N)	180	459	115	216	104	51
VSL (million euros)	640	1633	410	770	371	180

Rome

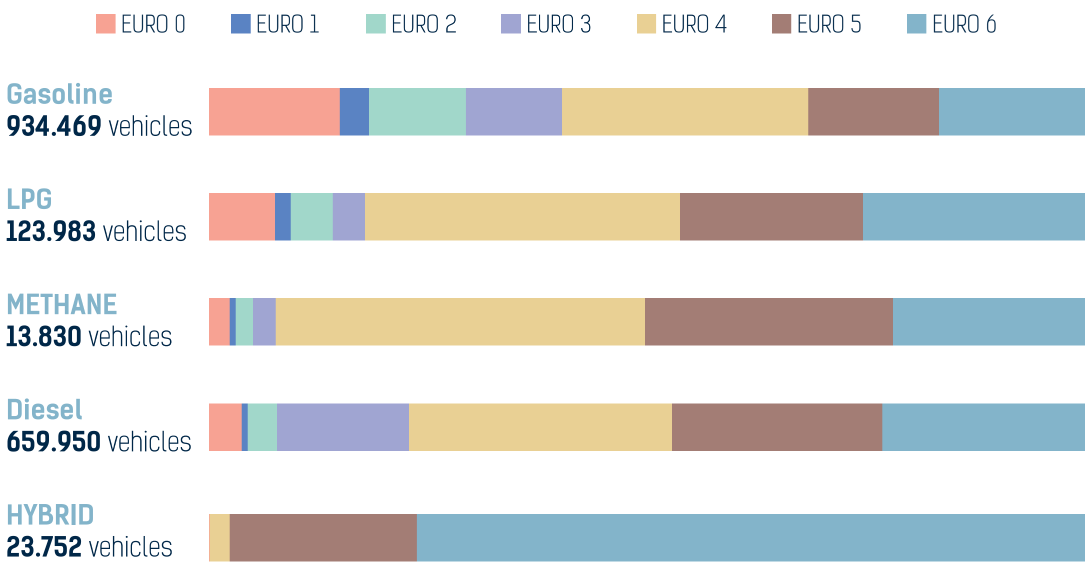
Passenger cars fleet

2018 Scenario

Segregation for fuel type



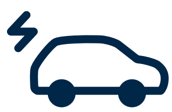
Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	180	459
VSL (million euros)	640	1.633

Electric Vehicles



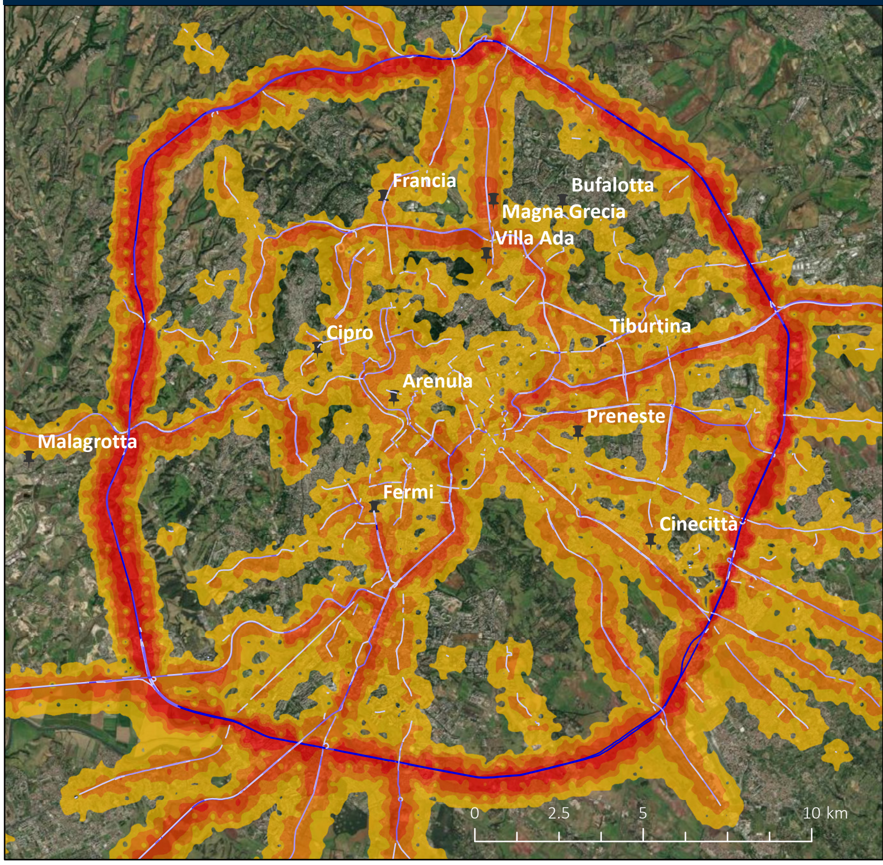
1.12 5

0,06% out of total number of vehicles

Rome

Air quality

2018 Scenario



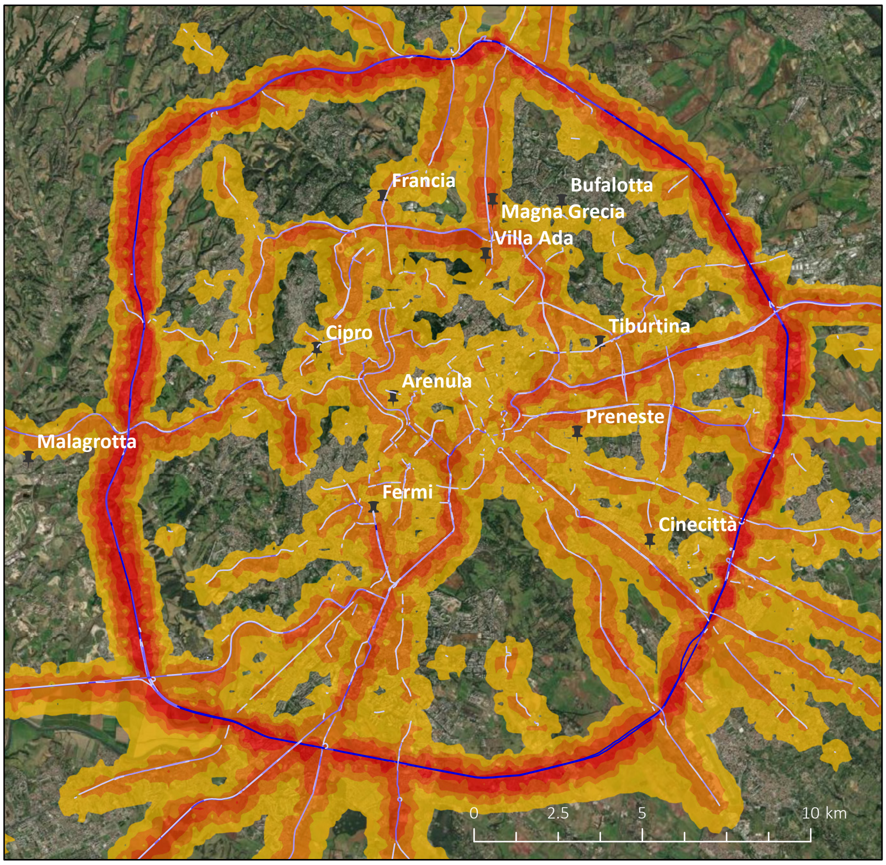
Flussi in veicoli/h

- 2100 - 2882
- 2883 - 3956
- 3957 - 5818
- 5819 - 8048
- 8049 - 11727
- Centraline di monitoraggio

NO_2 base

Concentrazioni in µg/m³

- < 3,8
- 3,8 - 11
- 11 - 21
- 21 - 38
- 38 - 50



Flussi in veicoli/h

- 2100 - 2882
- 2883 - 3956
- 3957 - 5818
- 5819 - 8048
- 8049 - 11727
- Centraline di monitoraggio

PM_{10} Scenario base

Concentrazioni in µg/m³

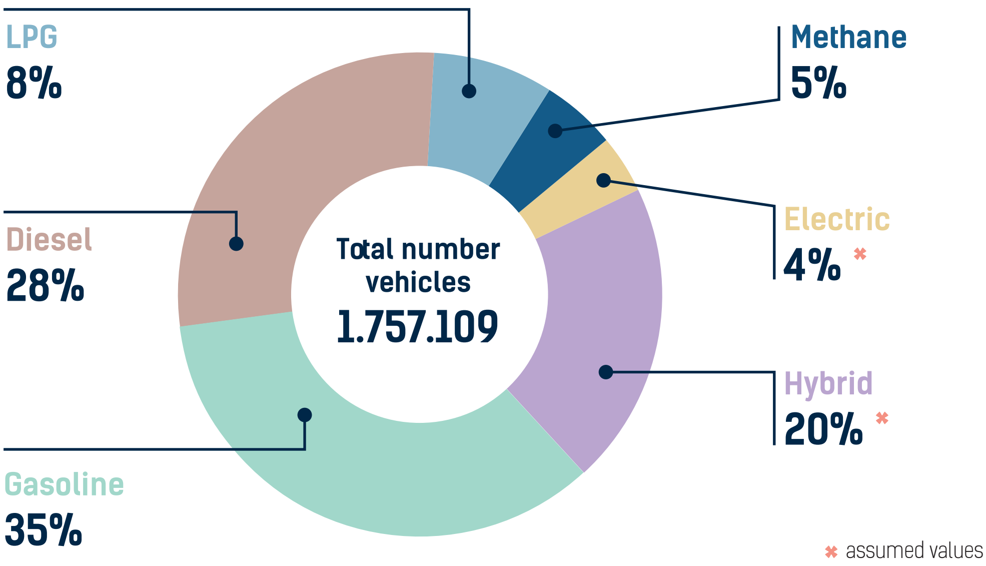
- < 1,5
- 1,5 - 4,4
- 4,4 - 8,9
- 8,9 - 16
- 16 - 22

Rome

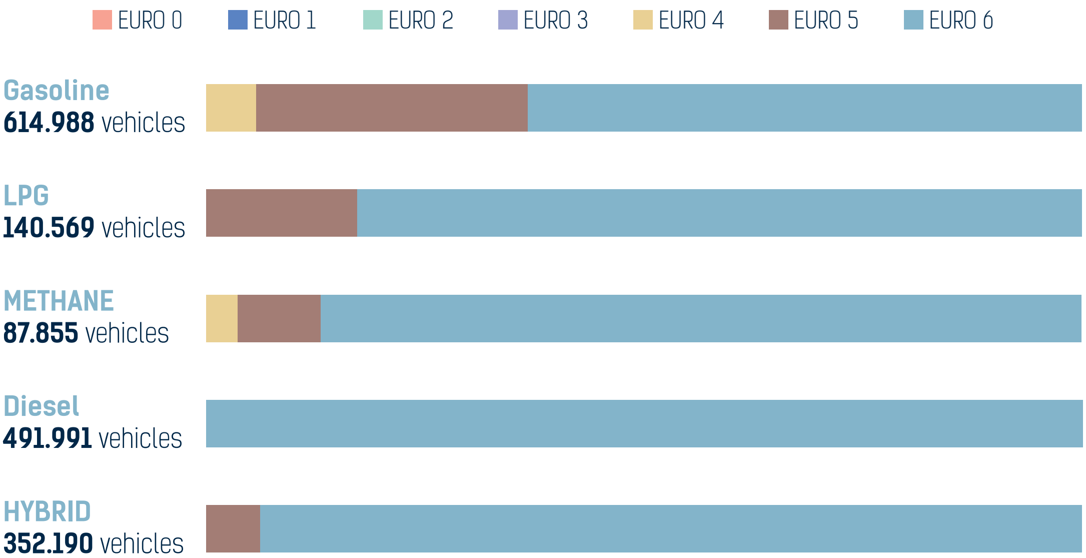
Passenger cars fleet

2025 Scenario

Segregation for fuel type



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature de aths	115	216
VSL (million euros)	410	770

Electric Vehicles

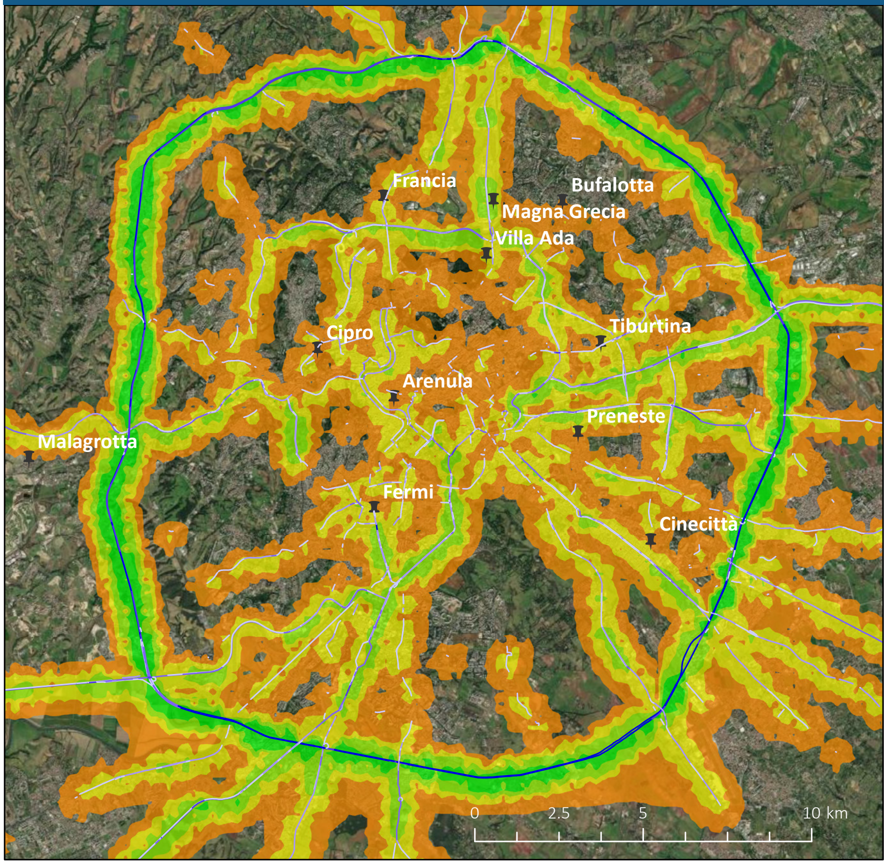
70.284

4% out of total number of vehicles

Rome

Air quality

2025 Scenario



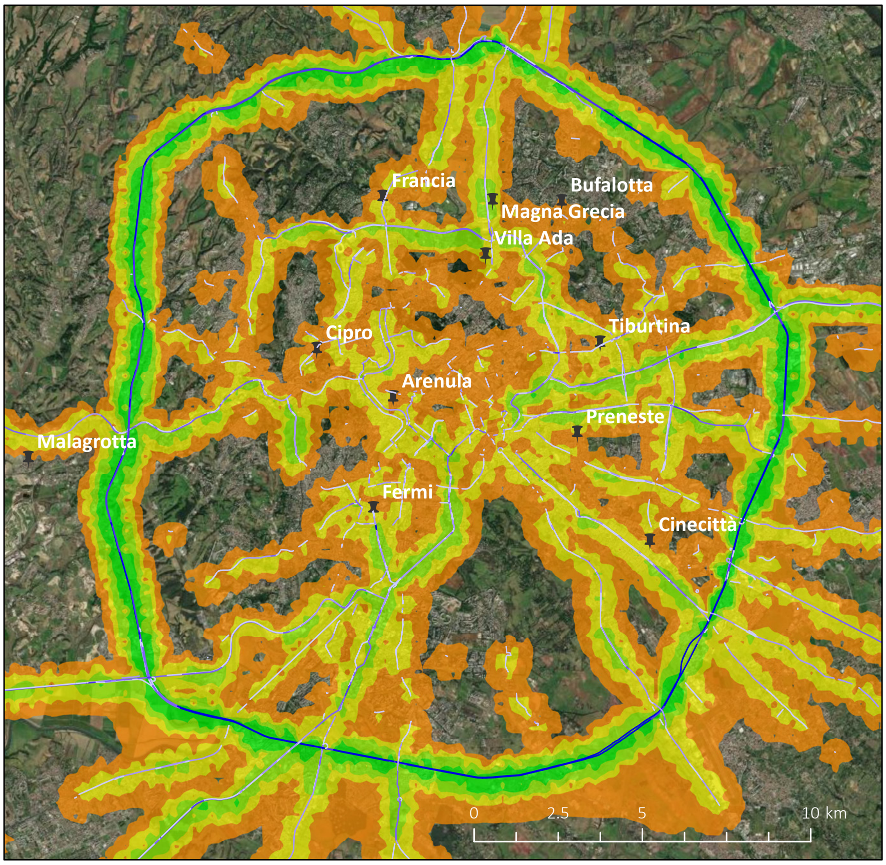
Flussi in veicoli/h

- 2100 - 2882
- 2883 - 3956
- 3957 - 5818
- 5819 - 8048
- 8049 - 11727
- Centraline di monitoraggio

NO_2 2025 vs base

Differenza in μg/m³

- < 1,8
- 1,8 - 5,1
- 5,1 - 10
- 10 - 18
- 18 - 39



Flussi in veicoli/h

- 2100 - 2882
- 2883 - 3956
- 3957 - 5818
- 5819 - 8048
- 8049 - 11727
- Centraline di monitoraggio

PM_{10} 2025 vs base

Differenza in μg/m³

- < 0,5
- 0,5 - 1,5
- 1,5 - 2,5
- 2,5 - 4,5
- 4,5 - 9

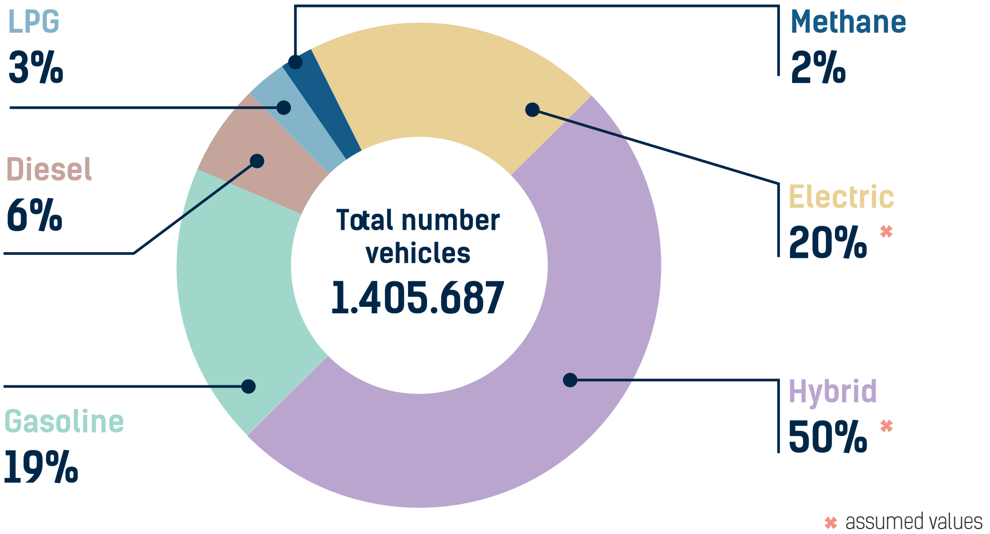
Rome

Passenger cars fleet

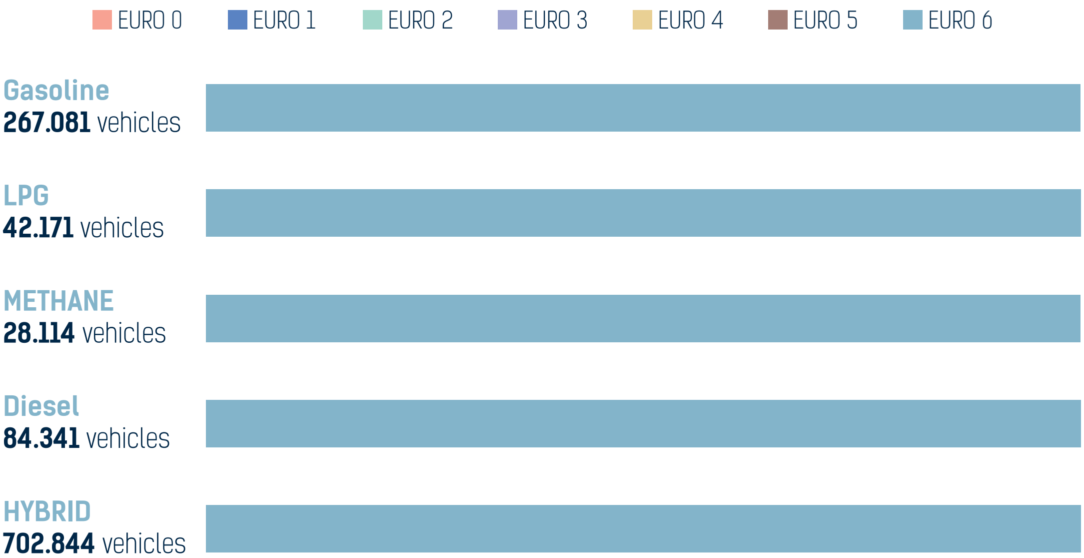
2030 Scenario

Segregation for fuel type

Total circulating fleet reduced by 20%



Segregation for Euro class



Mortality and economic impact

	PM_{10}	NO_2
N° premature dea ths	104	51
VSL (million euros)	371	180

Electric Vehicles

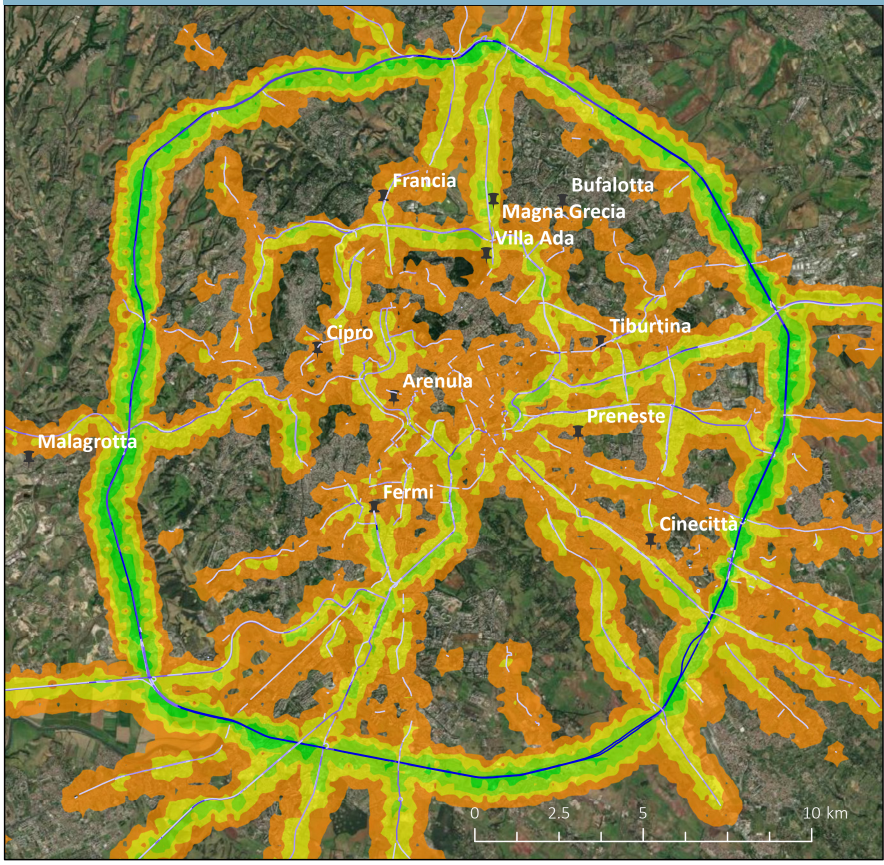
281.137

20% out of total number of vehicles

Rome

Air quality

2030 Scenario



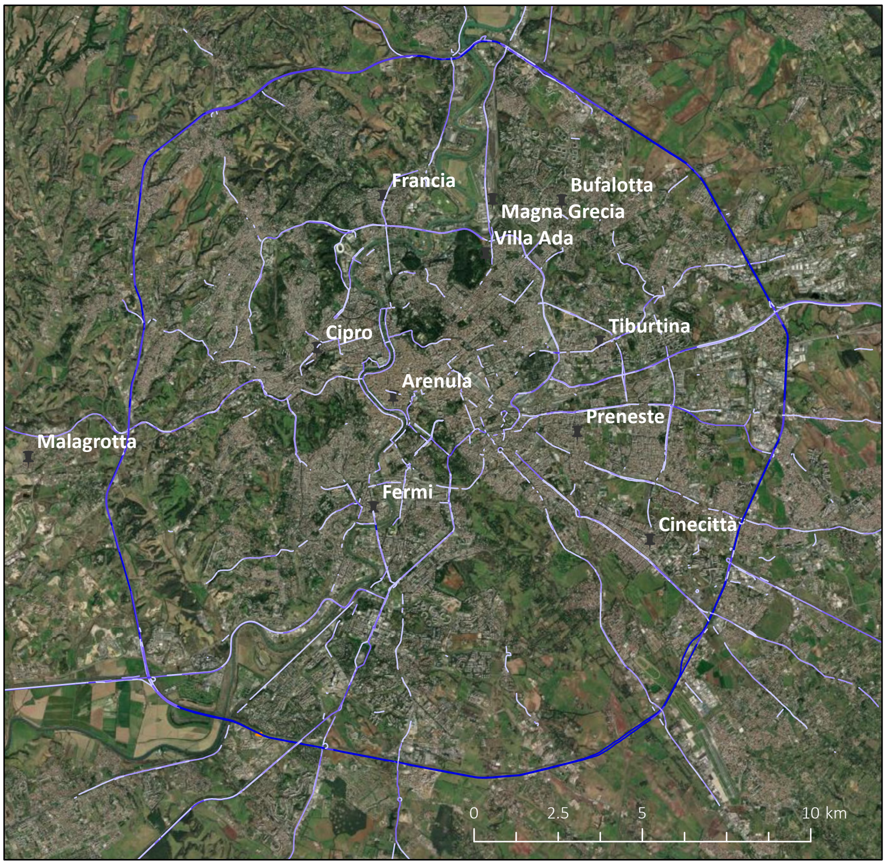
Flussi in veicoli/h

- 2100 - 2882
- 2883 - 3956
- 3957 - 5818
- 5819 - 8048
- 8049 - 11727
- Centraline di monitoraggio

NO_2 2030 vs 2025

Differenza in µg/m^3

- < 1,8
- 1,8 - 5,1
- 5,1 - 10
- 10 - 18
- 18 - 39



Flussi in veicoli/h

- 2100 - 2882
- 2883 - 3956
- 3957 - 5818
- 5819 - 8048
- 8049 - 11727
- Centraline di monitoraggio

PM_{10} 2030 vs 2025

Differenza in µg/m^3

- < 1,8
- 1,8 - 5,1
- 5,1 - 10
- 10 - 18
- 18 - 39

Conclusions

The study in question has made it possible to highlight how vehicular traffic is one of the main causes of pollution in urban areas, responsible for too many premature deaths and requires the community to bear considerable social and economic costs.

The COVID-19 pandemic and the consequent lockdown in the months of March and April 2020 led to a drastic drop in the concentrations of both gaseous and particulate pollutants with a consequent reduction in pollution worldwide observed in many cities around the world (London, Los Angeles and Mumbai) (Baldasano et al. 2020). In this period of drastic reduction in vehicular traffic in which a variation in movements of up to -93% compared to the average values was recorded, the concentrations of pollutants in traffic stations, representative of the average traffic of the area, of the cities of Rome, Turin, Milan and Naples recorded a decrease of up to 71% for NO_2 and 27% for PM_{10}. Considering the consequences related to the reduction of emissions from vehicles, the study analyzed the potential benefits in terms of reduction of air pollution and economic costs, attributable to premature deaths associated with pollutants linked to traffic in the urban area, assuming two different scenarios (2025 scenario and 2030 scenario) of electric vehicle penetration in urban contexts.

From the results obtained it is evident that, within a broader scenario of replacement of the private vehicle fleet, the penetration of a percentage of electric vehicles (4% - private vehicles - and 5% - light commercial vehicles for the scenario to 2025 and 20% - private vehicles - and 15% light commercial vehicles - for the 2030 scenario) play a fundamental role in reducing the concentrations of local pollutants, in particular NO_2. In fact, there is a reduction in concentrations, in percentage terms relating to the mobility sector, from a minimum of 47% (case of Bologna) to a maximum of 62% (case of Rome) considering the scenario at 2025, while taking into consideration the scenario at 2030 there is a reduction ranging from 74% (Palermo case) to a maximum of 89% (Rome case).

Small impact, but still important for PM_{10}. If the results of the 2025 scenario are observed, the reduction percentage starts from a minimum of 28% (in the case of Bologna) up to a maximum of 38% (in the case of Palermo); for the 2030 scenario, the abatement is not as significant as for NO_2, the reduction varies between 34% and 46%.

In the study, the reductions in the social cost expressed by the VSL (Value of Statistical Life) and as a function of the number of premature deaths were estimated. The number of premature deaths avoided by passing from the hypothesized scenario in 2025 to the scenario in 2030 is shown below.

Number of deaths avoided (N)

	2025 Scenario		2030 Scenario	
	PM_{10}	NO_2	PM_{10}	NO_2
Turino	22	83	23	144
Milan	97	394	110	536
Rome	65	243	76	408
Bologna	7	27	9	46
Palermo	15	49	18	69

The reduction in the number of deaths for cities such as Milan, Rome and Turin in relation to the concentrations of NO_2 and PM_{10} is significant, considering the assumptions reported in the appendix.

The social cost (VSL) associated with the number of deaths avoided, linked to the changes in concentrations of PM_{10} and NO_2 due to the contribution of traffic alone, which occur in the different hypothesized scenarios, varies between about 140 million and about 2 billion euros to the scenario 2025, and about 222 million and 3 billion in the 2030 scenario.

Social costs saved VSL (millions of euros)

	2025 Scenario	2030 Scenario
Turino	340	633
Milan	2.180	2.866
Rome	1.092	1.720
Bologna	140	223
Palermo	120	336

Considering the results obtained from the estimates developed in the study and the reductions in PM_{10} and NO_2 concentrations expected in the two scenarios, due to the penetration of electric vehicles into the vehicle fleet, the scenarios identified could provide substantial benefits not only in environmental terms, but also in health and cheap. If hypothesized throughout the national territory and beyond the territorial borders, they would contribute to respecting the programmatic objectives set at the national and European level.

Methodology, assumptions and limitations

Curated by Valeria Rizza e Francesco Petracchini

The study examines and compares two prospective scenarios, respectively in 2025 and 2030, of the current fleet of vehicles relating variably to the private transport sectors, of the logistics of the five Italian cities under study.

For the analysis, the ADMS (Advanced Dispersion Modeling System) - Roads simulation model was adopted on the basis of specific meteorological data for each city examined and according to the traffic flows for each sector of urban mobility analyzed and provided by the administrations themselves.

The basic scenario was calculated using the estimate of the concentrations of the pollutants PM_{10} and NO_2, starting from the vehicle flows to determine the emissions for each road link that makes up the city road network, providing an estimate of the contribution of vehicle traffic in the area under examination (not all other sources of emissions were considered). The traffic flows provided by the cities relate to 24 hours, and the meteorological data relate to a typical winter weekday (wind speed and direction, atmospheric stability, temperature, humidity, precipitation rate, cloudiness).

The scenarios provide for an increase in the percentage of technologies plug-in / electric hybrids in the vehicle fleet considering at the same time, the reduction of the percentages relating to internal combustion technologies such as petrol and diesel. And also, the progressive "rejuvenation" of the existing vehicle fleet in terms of environmental class.

The emission factors of the Italian context relating to the fuel categories of petrol, diesel, LPG, natural gas and hybrid, used to calculate the emission rate (g / km / s) were obtained from the database of the Italian Institute for Environmental Protection and Research, (ISPRA) for the year 2017, which are calculated both with respect to the kilometers traveled and with respect to consumption, with reference to both the detail of the technologies and the aggregation by sector and fuel.

The reductions in the concentrations of PM_{10} and NO_2 relating to the transport sector, reported in the two-time scenarios imagined, are attributable to the redistribution of technologies, the scrapping of the most polluting ones as well as the increase in penetration percentages relating to electricity and 'hybrid. The percentages of concentrations were calculated considering the ARPA monitoring stations as receptor points.

The short-term health impacts and economic costs of exposure to PM_{10} and NO_2 were estimated using the Environmental Benefits Mapping and Analysis Program (BenMAP: https://www.epa.gov/benmap), a tool for health impact assessment designed by the US-EPA (Boldo et al. 2011; Broome et al; Fann et al.).

The data used in this model and collected from the national statistical and health registries include several inputs:

- The air quality data, the outputs of the ADMS-Roads model for peak hours (8:00) at the receptor points (traffic monitoring stations) have processed and introduced into the BenMAP: the impact on health is associated to the contribution of traffic in the specific to the private sector and light commercial vehicles in relation to a base scenario in which the concentrations of PM_{10} and NO_2 correspond to the current scenario (2019), in which the percentages relating to electric vehicles are zero or very contained. A second scenario was performed to model the planned reductions for the year 2025, when the percentage of electric vehicles of private cars and light commercial vehicles is respectively 4% and 5%. A third scenario was performed to model the planned reductions for the year 2030, when the percentage of electric vehicles of passenger cars and light commercial vehicles is respectively 20% and 15%.
- The population analyzed is between 0 and 99 years old
- Incidence data: incidence data were collected according to the WHO International Classification of Diseases (ICD) code: ICD-10 A00 -R99 (all-cause mortality)
- Health impact functions: concentration-response relationships were selected to determine the short-term effects for PM_{10} and NO_2, in the specific case Atkinson et al. (2014) and Biggeri et al. (2004)
- Economic evaluation: the economic value of deaths related to air pollution is quantified using the Value of Statistical life (VSL)

The negative effects of air pollution also have an economic dimension, in fact they involve costs both of a health nature, due to treatment, and of a social nature, linked to the lower quality of life of people. The monetary estimate of these costs provides information on the economic burden borne by the community in terms of expenses for the treatment of diseases related to the effects of pollutants, and for the inconvenience and loss of collective well-being consequent to a worsening of health and quality of the life of subjects exposed to pollution. This aspect can constitute a useful informative contribution in the formulation of policies aimed at environmental sustainability in the transport sector.

Today the attention of epidemiological studies is growing towards the impact of particulate emissions in its various fractions and in particular of PM_{10} and in relation to NO_2. The epidemiological literature is generally in agreement regarding the damage to health caused by the presence of pollutants, the intensity of the phenomenon associated with the dose-response coefficient is still being studied and investigated. The dose-response coefficient expresses the statistical relationship that links the concentration of pollutants (in this case PM_{10} and NO_2) to the occurrence of damage to health, providing risk estimates related to exposure.

As regards mortality, epidemiological studies have developed specialized and very different researches, not only in terms of method, but also of approach to the problem, distinguishing short-term impacts (acute mortality) - when these effects are consequent to an increase the level of pollutants in the air, from long-term ones (chronic mortality) – when the effects occur at a distance after a long period of exposure.

To translate premature deaths into economic costs, the WHO-OECD study uses the "value of statistical life" (VSL) methodology. In practice, it is estimated the value that the various companies are willing to pay to avoid these deaths and these diseases: the value is differentiated according to the various economic contexts (for example, a life in Italy, for statistical purposes, can "be worth" about $ 3 million, $ 490,000 in Kyrgyzstan and $ 6.28 million in Luxembourg).

In this study, an analysis of the economic costs related to premature deaths due to the short-term effects of exposure to PM_{10} and NO_2 concentrations, relating only to the transport sector, was conducted for the five cities involved.

Fleet electrification scenarios – The scenarios provide for an increase in the percentage of penetration of hybrid plug-in / electric technologies on the vehicle fleet in circulation while considering the reduction of the percentages relating to internal combustion technologies such as gasoline and diesel. For each category, vehicles are divided into fuel (petrol, diesel, LPG, natural gas, electricity and hybrid) and emission standards (Euro 0, Euro 1, Euro 2, Euro 3, Euro 4, Euro 5, Euro 6).

Traffic flows – The dataset of traffic flows represents the main data on which all the simulation was set up and allows to outline the sources (characterization of the emission sources) or the traffic flows to private vehicles, light commercial vehicles and LPT (where the data is present) for road arch.

Turin (5T) – Flows are available for each hour of a typical winter weekday. The simulation was carried out considering for each arc the traffic flows of the private sector and of the logistics (excluding heavy vehicles) which 5T defines as light vehicles. In fact, 5T groups vehicles into two categories, namely light vehicles (motorcycles, cars and minivans, cars and minivans with trailers, vans and vans) and heavy vehicles (trucks, lorries, articulated lorries, buses, unclassified vehicles).

By assuming as a percentage relating to the two sectors that relating to the composition of the vehicle fleet and neglecting the percentages of motorcycles from the traffic flows, the classification of the "Private" sectors (cars and minivans, cars and minivans with trailers) and "light commercial vehicles "(Vans and pickup trucks). From the analyzes carried out on the components of the vehicle fleet, the penetration of light commercial vehicles on the private sector was therefore extrapolated, obtaining a penetration percentage of around 10% consistent with the analyzes carried out in Bologna (in which the traffic flow data was already divided between private and light commercial vehicles).

Bologna – TGM (Average Daily Traffic) is available for each link. The distribution of flows in the city of Bologna was analyzed and it emerges that the period of greatest vehicular flow falls within a period of 8 hours, for which the TGM was divided over 8 hours to obtain the hourly flow.

Palermo – Simulation with flows of the private transport sector only. Logistics traffic flows have not been provided, only surveys are present.

Milan – Simulation carried out for the private transport sector only.

Rome – Simulation carried out for the private transport sector only. Only flows greater than 2100 vehicles / h were considered, given the limitation of the number of sources that the software allows to implement, in order to analyze above all, the contribution from the GRA traffic.

Simulation period – The simulation period analyzed is the month of January, relative to the winter period and the most critical in terms of concentration, identified by referring to the reports of the respective ARPA of each city, in which the data of the average concentrations of PM_{10} are present. and NO_2 for each month of the year. Once the choice of the period was made, they were identified the most critical days falling in January for which the simulation was carried out with the ADMS-Roads model.

Composition of the vehicle fleet – The composition of the vehicle fleet refers to the year 2018. Information relating to the number and type of vehicle was obtained by consulting the ACI (Automobile Club Italia) database.

For each road link, representing an emission source and characterized by a non-zero value of traffic flow, the distribution of the technological classes and environmental classes is considered uniform throughout the urban territory.

Emission Factors – The emission factors (g / km) related to the fuel categories of petrol, diesel, LPG, natural gas and hybrid, used for the calculation of the emission rate (g / km / s), implemented in the system to obtain the estimated concentrations, were obtained from the database of the Higher Institute for Environmental Protection and Research (ISPRA) for the year 2017 relating to the Italian context, which are calculated both with respect to the kilometers traveled and with respect to consumption, with reference both to the detail of the technologies and to the aggregation by sector and fuel. Unlike the factors provided by the EMEP / EEA database, the emission factors of the ISPRA database are expressed as a function of the characteristics of the Italian vehicle fleet (average age of the vehicle fleet).

The emission factors provided by ISPRA also take into account the "non-exhaust" components, that is, the emissions resulting from the wear of the brakes, road surface and tires in accordance with the database provided by the European Environmental Agency (EEA). On the other hand, the portion due to the re-suspension (both for ICE vehicles, with internal combustion engines and for electric vehicles) is not assessed (since there is no consistent methodology to date).

The emission factors refer to the following technologies: petrol, diesel, LPG, methane and hybrid. As far as the emission factors for the electric vehicle are concerned, to date there is no consolidated methodology for which their estimate was derived using the research results of Simons et al. (2013) and Timmers et al. (2016). Electric vehicles are 24% heavier than internal combustion technologies, this observation was made based on comparisons between passenger cars of a conventional model and an electric equivalent.

This made it possible to highlight that electric vehicles on average are heavier than 280 kg. Using Simons (2013) research results, Timmers estimated that a 280 kg weight gain would produce an increase in PM_{10} of 1.1 mg per kilometer (mg / vkm) for tire wear, 1.1 mg /vkm for brake wear and 1.4 mg /vkm for road surface wear. Also, for the application of regenerative braking there are still no methodologies that agree on how much the latter reduces emissions due to wear of the braking systems, so in accordance with the results of the work of Timmers et al. (2016), which reports that the emissions resulting from brake wear for EV vehicles are negligible and therefore equal to zero, was not considered.

Meteorological parameters – Meteorological data (wind speed and direction, atmospheric stability, temperature, humidity, precipitation rate, cloud cover) are related to a typical winter weekday. These are the atmospheric parameters that have the greatest influence on the dispersion of pollutants and therefore on the calculation of concentrations.

Receptor points – They can be arranged in a regular manner in a calculation grid (which can have different configurations: Cartesian, polar, etc.) in which the spatial resolution of the concentrations calculated for the entire study domain is defined. The receptor points can also be defined in specific positions ("discrete" receptors) such as, in this case, in correspondence with the air quality monitoring units belonging to the ARPA network.

More electric mobility: future scenarios and air quality in Italian cities

February 2020
Motus E – CNR Institute of Atmospheric Pollution Research

Graphic design, information architecture,
infographics and layout: Giorgia Ghergo – Heap Design

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curated by **Valeria Rizza, Francesco Petracchini, Dino Marcozzi e Francesco Naso**

ISBN: 978-88-6224-023-9