Diesel, petrol or electric vehicles: What choices to improve urban air quality in the Ile-de-France region? A simulation platform and case study

Michel Andre, Karine N. Sartelet, Sophie Moukhtar, Jean-Marc André, Matteo Redaelli

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M. André[1], K. Sartelet[2], S. Moukhtar[3], J.M. André[4], M. Redaelli[5]

[1] IFSTTAR, Bron, 69675, France, michel.andre@ifsttar.fr

[2] CEREA, Joint laboratory Ecole des Ponts ParisTech - EdF R&D, 77455 - Marne-la-Vallee, France

[3] Airparif, 75004 - Paris, France

[4] CITEPA, 75010 - Paris, France

[5] ANSES, 94701 - Maisons-Alfort, France

Abstract

Air pollution from road traffic and its mitigation is a major concern in most cities. A platform for simulating pollutant emissions and concentrations was developed and applied to the Île-de-France Region (Greater Paris) of France, taking account of anthropogenic and natural sources and 'imported' pollution from elsewhere in France and Europe. Four technological scenarios for 2025 were studied and compared to the 2014 reference situation (1-REF). These scenarios included the current evolution of the park with widespread adoption of diesel particulate filters (DPFs) (2-BAU), decline in the sale of diesel vehicles and a corresponding increase in petrol vehicle sales (3-PET), promotion of electric vehicles in urban areas (4-ELEC), and a combinaison with a decrease in traffic of about 15% in the densely populated area inside the A86 outer ring road (5-AIR). The corresponding vehicle fleets were determined using a fleet simulation model.

Traffic pollutant emissions were computed with the COPERT4 European methodology and hourly traffic data over the Île-de-France road network. Particulate matter (PM_{10}, $PM_{2,5}$ and $PM_{1,0}$), particles number (PN), black carbon (BC), organic matter (OM), nitrogen oxides (NOx) and nitrogen dioxide (NO_2), non-methane volatile organic compounds (VOC), ammonia (NH_3), carbon monoxide (CO) and carbon dioxide (CO_2) were considered. Emissions for other sectors were taken from a regional inventory. Emissions outside the Île-de-France region (Europe and France) were derived from the European and French emission inventories. Pollutant concentrations ($PM_{2,5}$, PM_{10}, organic and inorganic PM_{10}, PN, BC, NO_2 and O_3) were simulated over nested domains (Europe, France and Île-de-France) using the Polyphemus platform for two scenarios (2-BAU and 3-PET). Methodological aspects and results for Île-de-France are discussed here.

All scenarios led to a sharp decrease in traffic emissions in Île-de-France (-30% to -60%) by 2025. The decline in diesel induced a stronger renewal of the fleet. PM and NOx emissions were more strongly reduced than VOC or NH_3. Traffic reduction reduced all emissions in the densely populated area within the A86 outer ring road (-20% to -45% for exhaust particles and gaseous pollutants).

The 2-BAU and 3-PET scenarios lowered annual average concentrations, especially for NO_2 and BC, and more strongly influenced daily-peak than daily-average concentrations. In Île-de-France, PM of diameter <10 µm (PM_{10}), and NO_2 concentrations, decreased in the most densely populated areas. The entire population would benefit from a PM_{10} annual mean concentration decrease of ≥0.4 µg/m^3, and the annual mean NO_2 concentration would decrease by ≥10 µg/m^3 for 40-50% of the population. For other

pollutants ($PM_{2.5}$, secondary pollutants, etc.), reductions were more limited, due to the other activity sectors and atmospheric chemistry. Ozone concentrations might even increase in urban locations, suggesting an increase in oxidants and thus an increase in secondary aerosol formation if precursors were not reduced.

Differences between 2-BAU and 3-PET scenarios were slight. For PM and NO_2 concentrations, the petrol scenario was slightly more favorable than the “business-as-usual” scenario with diesel vehicles and DPF; differences were strong for primary particles and NO_2 and weak for secondary compounds. This slight advantage was due to lower emissions and accelerated fleet renewal (higher proportion of Euro 5 & 6).

Keywords

Road traffic, pollutant emission, concentration, simulation, vehicle technology, vehicle fleet, scenario, COPERT, Polyphemus

1 Introduction

Air pollution is a major concern in most European cities and road traffic is often considered as one of the main causes even though other sources can contribute significantly. Development and promotion of vehicle technologies and traffic restrictions (e.g., Low Emissions Zones) are levers frequently considered for improving air quality, although their actual effectiveness is rarely established. Among the issues in France, there are several questions regarding diesel cars, progress in design and the actual efficiency of particulate filter and NOx depolluting systems. Gradual replacement by petrol-driven cars, or even prohibition in city centers, is sometimes envisaged, as is the promotion of electric or alternative-power vehicles.

As part of a larger study on the health effects of ambient particulate matter, the ANSES (French Agency for Food, Environmental and Occupational Health & Safety) was asked to investigate the progression in air pollution on various scenarios of road traffic progression, and the impact of vehicle technologies. A working group with several research laboratories and institutions undertook a large state-of-the-art study of the emissions and atmospheric concentrations of pollutants in France, their past and projected progression, the specific contributions of road traffic and other sources, and gaps in the knowledge (André et al., 2019). In this framework, a simulation study over France and the Île-de-France (Greater Paris) area was conducted to analyze the progression in emissions and concentrations under different assumptions regarding vehicle technologies. Methodological aspects and results for the Île-de-France region are discussed here.

2 Case study

The Île-de-France region is the most populated region of France (12 million inhabitants in 2014, 19% of the national population), with a density of 1,000/km^2. Paris covers a little less than 1% of the area of Île-de-France but more than 20% of its population (2.3 million). The area within the A86 outer ring road (see Figure 1) accounts for approximately 3% of the area (including Paris) and 41% of the Île-de-France population. Thus, the A86 marks the outer boundary of a dense and highly populated urban area.

The main sources of anthropogenic pollutant emissions in Île-de-France are road traffic (56% of NOx, 28% of PM_{10}), the residential sector (in particular its contribution to emissions from wood burning), the tertiary or service sector (18% of NOx, 26% of PM_{10}), and agriculture (91% of NH_3, 18% of PM_{10}). Due to a slight decrease in road traffic in Île-de-France and to a strong reduction in exhaust emissions (around -60% in PM_{10} and -48% in NOx over the period 2000-2012), pollutant concentrations have also decreased, by about -25% for PM_{10} and $PM_{2,5}$ (annual mean concentrations), and by about -45% near main roads. Despite these improvements, exceedances of European regulatory standards and exceedances of air quality guidelines (PM_{10}, NO_2, O_3) remain, as well as peak pollution episodes.

The Île-de-France Region was used here as a case study for analyzing the progression in pollutant emissions and atmospheric concentrations under different scenarios with various vehicle technologies. One scenario also included a reduction in traffic volume.

3 Method, tools

The approach consisted in simulating pollutant emissions and atmospheric concentrations under different scenarios with different compositions of the vehicle fleet. These scenarios corresponded to different options (renewal of diesel vehicles, promotion of petrol or of electric vehicles, traffic reduction).

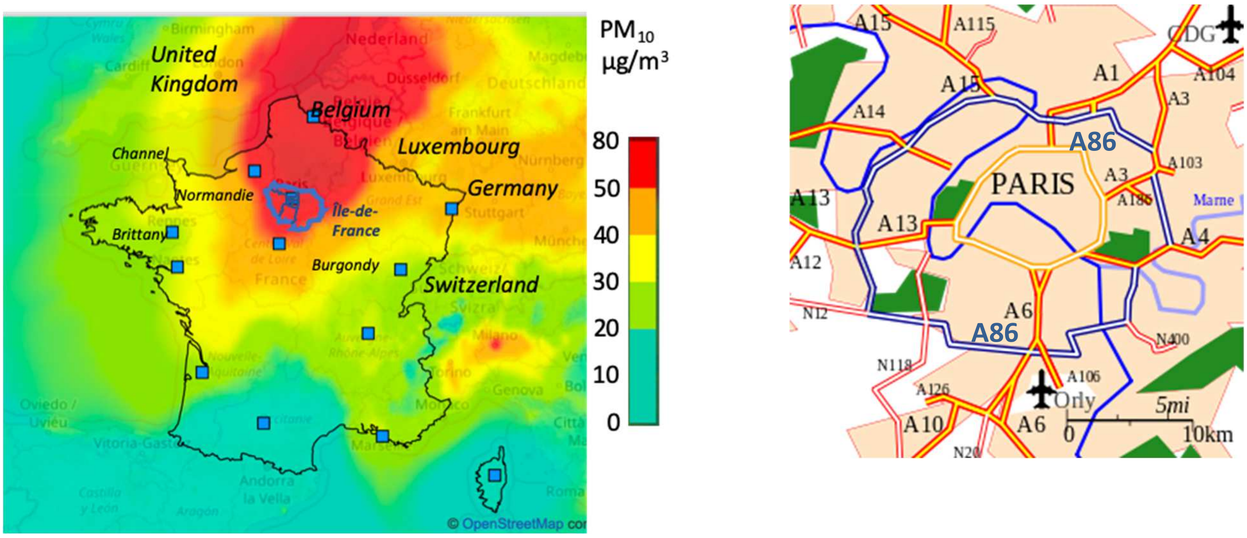


Figure 1: The Île-de-France Region during a PM_{10} pollution episode in February 2018 (source: Prevair http://www2.prevair.org, left); main roads and A86 motorway (in blue) delimiting the area within the A86 outer ring road (right)

The overall analysis of air quality required an estimation of the pollutant emissions from all activity sectors, as well as natural emissions and imports of pollution from neighboring areas. It was also necessary to model the transport and physico-chemical transformations of atmospheric pollutants, which depends on contextual conditions such as the chemical regime of the atmosphere.

Three nested domains were considered for the simulation: Europe, metropolitan France, and the Île-de-France region (for the outcome of the present case study) (Figure 2). Pollutant emissions from road traffic were computed according to the scenarios for France and Île-de-France, while emissions from the other sectors were derived from the national and regional inventories and were invariant. Weather conditions were also kept constant. Concentrations were simulated successively over 3 nested domains

(Europe, France, and Île-de-France) to estimate the boundary conditions and transfers between the domains.

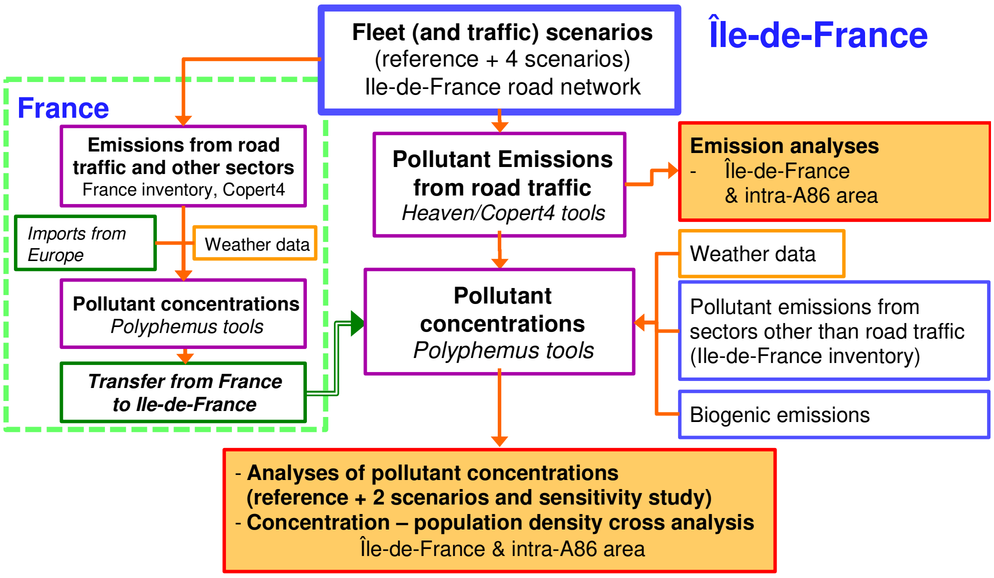


Figure 2: Block diagram of the simulations of pollutant emissions and atmospheric concentrations.

Selection of the examined pollutants was based on their relevance to the particulate pollution (particulate fractions, precursor gases), to the traffic-related air pollution, and to air quality issues. The presence in ambient air of gaseous pollutants and particulate matter has harmful effects on human health and the environment (WHO Europe, 2013). The issues of particulate matter (PM) and nitrogen dioxide (NO_2) in ambient air are of particular concern in urban areas, such as the Île-de-France region, that have high levels of PM and NO_2 concentrations when compared to air quality standards and objectives designed to protect human health. The impact of exposure to ambient air $PM_{2.5}$ due to human activity has been estimated at 48,000 premature deaths per year in France. This is exacerbated in urban areas with more than 100,000 inhabitants, where results show an average loss of 15 months of life expectancy at 30 years of age due to this $PM_{2.5}$ exposure (Pascal et al., 2016). Concentrations of particulate matter in ambient air have decreased over the years, but still exceed the annual air quality guidelines recommended by the World Health Organization for $PM_{2.5}$ (WHO Europe, 2006). Among the particulate components, there is increasing evidence of adverse health effects from exposure to BC (and the pollutants adsorbed on the carbon core) which is largely emitted by road traffic in urban areas (Jacquemin et al., 2019). The PM ambient air concentration also comes from emitted gases, especially NO_2, NH_3, and v VOC, which condense and react to form secondary aerosols (Seigneur, 2019). Besides the pollutants related to air quality issues, road traffic is one of the main anthropogenic sources of CO_2 (CITEPA, 2016a), a well-known and policy-relevant greenhouse gas. Therefore, the following pollutants were selected for simulating emissions: particulate matter (PM_{10}, $PM_{2,5}$, $PM_{1,0}$), particulate number (PN), black carbon (BC), organic matter (OM), nitrogen oxide (NOx) and nitrogen dioxide (NO_2), volatile organic compounds (VOC), ammonia (NH_3) carbon monoxide (CO) and carbon dioxide (CO_2). For simulation of atmospheric pollutant concentrations, the following pollutants were specifically analyzed amongst the outputs of the air-quality model: $PM_{2,5}$, PM_{10}, organic and inorganic PM_{10}, PN, BC, NO_2 and O_3.

The following sections describe the scenarios and platform used for simulating pollutants emissions and concentrations.

3.1 Fleet scenarios and data

Vehicle fleet composition scenarios were designed with two main objectives:

- To observe the evolution of road traffic emissions and the implications for pollutant concentrations over a ten-year horizon,
- To consider different plausible technological options within this horizon, in relation to current concerns (pollution from diesel engines) and the remediation measures envisaged.

The vehicle fleet evolution was estimated using a model which simulates a realistic fleet renewal (introduction of new vehicles and withdrawal of old ones, André et al. 2016), under different assumptions regarding technological choices. The reference fleet compositions (Île-de-France and France) were those observed for the years 2013 to 2014. Scenarios and evolution of fleets were then considered for the 2025 horizon. The scenarios were designed as follows:

- 1-REF: the 2014 reference situation, with the actual vehicle fleet compositions in France (2013) and Île-de-France (2014).
- 2-BAU: This scenario aimed to characterize the evolution of pollution between 2014 and 2025, in a context of generalization of diesel particulate filters and renewal of the fleet with the evolution of regulations (high share of vehicles complying with recent emission regulations Euro5 and 6). This "business-as-usual" scenario corresponded to the expected evolution up to 2025. The balance between the engine types (petrol, diesel, electric) and between the categories and sizes of vehicles was unchanged.
- 3-PET: this scenario supposed a marked decline in diesel engines in favor of petrol for light vehicles (to reach an inversion of the diesel/petrol share in the 2025 fleet), by a steady decline in sales of diesel (from 60% to 5% in 2025), with the same regulatory evolution as for the 2-BAU scenario.
- 4-ELEC: this scenario supposed a marked promotion and increase in electric vehicles (EV) on the urban road network, for all vehicle categories. EV sales reach 40% of passenger cars and 60% of light commercial vehicles in 2025. All Euro 3 and earlier trucks and buses, and all motorized two-wheelers under 250cc, were also replaced with EVs. However, the shift towards electric drives only concerned the vehicle fleet in urban areas, while the vehicle fleet of the 2-BAU scenario was still used in rural areas and on motorways. On a regional scale, the proportion of electric vehicles in traffic reached 11% for light vehicles, 2% for trucks, 15% for buses and coaches and 42% for motorized 2-wheelers.
- 5-AIR: this voluntary scenario explores the combination of technological change and traffic reduction in dense urban areas to achieve air quality objectives. It combined the fleet composition of the 4-ELEC scenario and an overall reduction in traffic in the densely populated area within the A86 outer ring road by about 15%. The decrease in traffic mainly concerned private cars (-25%) compensated by an increase in motorized two-wheelers (+50%) and urban buses (+75%). Light commercial vehicle

and truck traffic decreased by 20% (without compensation). The trend towards electric motorization and traffic reduction applied only to this area. Outside that area, the traffic remained constant and the vehicle fleet of the 2-BAU scenario was used. On the scale of the region, traffic decreased by 4% and the proportion of electric vehicles was 4% for light vehicles, 1% for trucks, 6% for buses and coaches and 18% for motorized two-wheelers.

The first three scenarios were simulated for pollutant emissions and concentrations over France and Île-de-France. The last two were simulated only for emissions over Île-de-France.

3.2 Anthropogenic pollutant emissions

3.2.1 Île-de-France domain

For the Île-de-France region, road traffic emissions were computed using the Heaven Platform (Thomassini et al. 2003), and by considering actual hourly traffic data (flow and speed) over the road network (11,000 km of roads and 41,000 segments simulated). These traffic data were derived from real-time observations for the year 2012.

The Heaven Platform computed the emissions according to the hourly traffic flows on each road link, the number of vehicles per broad category and detailed technological class, their speed, proportion with cold engine, and ambient temperature. The exhaust and non-exhaust (brake and tyre wear, road abrasion) and evaporative emission factors and functions were those from the EMEP / EEA guidebook and COPERT 4 v11.3 methodology. For the exhaust particulate numbers, emissions from HBEFA 3.2 (Handbook of Emission Factors) were used. For evaporative VOC emissions, running and hot-soak losses were spatially distributed while diurnal losses (parked vehicles) were estimated on the regional scale.

The malfunctioning of engines and emission control systems, or their modification or removal (particle filters) are not explicitly considered here, as the emission models do not allow this. According to (T&E 2018) the removal of systems is on the increase in recent vehicles, but no real statistics are available (a few thousand cases have been recorded). Moreover, it is likely that these practices will remain limited in the future, in particular due to the restrictive evolution of regulations (periodic inspection of vehicles) and technologies (OBD, on-board diagnostics). Their influence on scenarios is therefore likely to be limited.

A detailed vehicle fleet composition in terms of technologies, fuels and emissions standards, derived from local surveys, was used for the reference situation (year 2014). This fleet composition was then adjusted according to the scenario’s assumptions. Traffic emissions were then estimated for all pollutants and scenarios and aggregated on a 1x1 km^2 mesh. For the other sectors, pollutant emissions were derived from the 2012 regional emission inventory (Airparif 2016) on a municipal scale, and spatialized on the 1 km^2 grid.

3.2.2 France domain

For metropolitan France, emissions from all activity sectors for 2013 were derived from the 2016 French inventory (CITEPA 2016a, CITEPA 2016b), mainly based on the EMEP/EEA Guidebook approach (EEA, 2013). Emissions were then spatially distributed using the 50 x 50 km^2 grid established for 2013.

The vehicle fleet scenarios applied in Île-de-France induced strong evolution of traffic emissions. It was thus critical to consider also emittent evolution of the fleet composition for France, otherwise there would have been important discrepancies in emissions between these two domains, and subsequent bias. The actual French vehicle fleet composition (different from the Île-de-France fleet) was thus used for the reference situation, and a similar process as that for Île-de-France was used for adjustuing it with the scenario assumptions. Road traffic emissions for France were derived from the national inventory for the reference situation, and adjusted for the scenarios by using the aggregated emission factors for the different vehicle fleet compositions.

3.2.3 Europe domain

For Europe, anthropogenic emissions were computed using the EMEP inventory (50 x 50 km^2 horizontal resolution, year 2014). Because of the large scale and thus low influence on the regional results, they were kept invariant between scenarios.

3.3 Pollutant concentration simulation by the air quality model Polair3D/Polyphemus

Polyphemus is a platform for air quality and atmospheric transport simulation, from urban to continental scale, including Gaussian and Eulerian models, data assimilation and inverse modeling tools (Mallet et al. 2007). The Eulerian chemistry-transport model Polair3D provides hourly concentrations, on a discrete meshed domain, of gaseous and particulate compounds, as well as the chemical composition of particulate matter by fractional size. Five classes of size are considered here, from 0.01 to 10 micrometers.

The dispersion is computed according to wind fields and mixing caused by turbulence. The chemical processes concern the different phases (gaseous, aqueous and particulate). The dynamic evolution of the particle size distribution is simulated, as well as the interactions between the phases, such as the heterogeneous reactions of certain gaseous compounds on the particle surface. Deposition processes remove pollutants from the atmosphere and transfer them to other media.

Secondary pollutants such as (O_3 and some particulate precursors are formed in the gas phase by reactions involving NOx and VOCs, depending on their respective concentrations (chemical regime of the atmosphere). Particulates consist of a complex mixture of dust, BC, inorganic components (sodium, sulphate, ammonium, nitrate, chloride) and organic matter (OM). The inorganic and organic compounds of particulates are largely secondary. OM precursors are volatile organic compounds of biogenic (isoprene, monoterpenese, sesquiterpenes) or anthropogenic (aromatics, intermediate and semi-volatile organic compounds) origin.

3.4 Set-up and model input data

Simulations were performed on three nested domains: Europe ([14.75°E, 34.75°E] x [35.25°N, 69.75°N] with a resolution of 0.5° x 0.5°), France ([5°E, 10°E] x_[41°N, 52°N] with a resolution of 0.1° x 0.1°) and Greater Paris ([1.35°E, 3.55°E] x_ [48.00°N, 49.50°N] with a resolution of 0.02° x 0.02°).

Detailed set-up and model input data may be found in Sartelet et al. (2018) and André et al. (2019). An evaluation of the modeled concentrations for 2014 by comparisons to measurements of O_3, NO_2, PM_{10}, $PM_{2.5}$, BC and OM is presented in Sartelet et al. (2018) and André et al. (2019).

Land-use data were obtained from the "Global Land Cover" and Corine databases. Meteorological data were derived from the ECMWF (European Center for Medium-Range Weather Forecasts) reanalyzes for the simulations over Europe and France, and from the WRF (Weather Research and Forecasting) model version 3.6 (Skamarock, 2008) for the simulations over Île-de-France (Kim et al., 2013). Marine salt emissions relied on Jaeglé et al. (2011) parameterization, while biogenic emissions were estimated using the Model of Emissions of Gases and Aerosols from Nature - MEGAN (Guenther et al., 2006).

The initial and boundary conditions of the Europe simulations were based on the global model MOZART-4 and the meteorological fields of the NASA GMAO GEOS-5 model. The concentrations simulated for Europe served as initial and limit conditions for the simulations over France, which themselves served as initial and boundary conditions for Île-de-France. The air quality simulations were carried out with 14 vertical levels between the ground and 12 km ([0 - 30m], [30- 60m], [60 - 100m], [100 - 150m], [150-200m], [200 - 300m], [300 - 500m], [500 – 750m] [750m – 1km], [1 – 1.5km], [1.5 – 2.4km], [2.4 - 3.5km], [3.5 – 6km], [6 - 12km]).

A detailed speciation of pollutant emissions (e.g. NOx into NO, NO_2 and HONO, VOCs, particulate mass (PM) into elemental carbon (EC), OM and dust) was needed for the simulations. The NOx, VOCs and particulate speciations were modified for each of the scenarios, in order to take into account the specificities of the vehicle fleet, as these speciations depend on engine type (for example, petrol vehicles tend to emit more aromatic compounds than diesel, while diesel vehicles tend to emit more NO_2). VOC speciations were derived from (Theloke and Friedrich, 2007), NOx and particulate speciations from EMEP guidelines (Ntziachristos et al., 2013).

Secondary organic aerosols (SOA) depend particularly on VOCs and ISVOCs (intermediate and semi-volatile organic compounds), the composition of which varies with the engine (diesel, petrol) and the emission control systems (DPF). ISVOCs are poorly known although they contribute significantly to the formation of organic particles. Gas-phase ISVOCs were estimated by multiplying by 1.5 the emissions of the primary organic compounds (Kim et al., 2016). An alternative approach using a SVOC / NMHC ratio was also tested in a sensitivity study (Sartelet et al., 2018).

3.5 Scenario assumptions and simulation conditions

The year 2014 was chosen as a reference base, while future scenarios were constructed for 2025.

In order to study the impact of technological options, road traffic emissions for France and Île-de-France were changed according to vehicle fleet scenarios, while most assumptions and input data were kept invariant. Notable invariants were weather conditions (2014), land cover, biogenic emissions and emissions from sectors other than traffic, populations and their geographic distribution, total traffic volume (except for one scenario with a traffic reduction) and its spatial and temporal distribution, the traffic shares of different vehicle categories, traffic conditions, and, more generally, mobility behavior and socio-economic context.

The geographic distribution of the simulated pollution was also cross-referenced with the spatial distribution of the populations approximated by their place of residence, in order to assess the impact of the scenarios on population exposure.

4 Results

4.1 Fleet compositions

The average fleet composition of Île-de-France for the different scenarios is described in Table 1. It was estimated by weighting the fleets typical of urban and rural areas, the Boulevard Périphérique (the Paris inner ring road), and highways. Light vehicles (passenger cars and light commercial vehicles) accounted for a very high proportion of traffic (86%), followed by motorized two-wheelers (8%). Trucks accounted for only 5% and buses / coaches less than 1%. The 2-BAU scenario doubled the equipment of light diesel vehicles with particulate filters and renewed almost the entire fleet to meet the Euro 5 and 6 regulations (from 40% to 80%). The 3-PET scenario reversed the diesel/petrol ratio from 73%-27% to 43%-56% (light vehicles). This important change required a greater renewal of the fleet, which broadly amplified the evolution towards Euro 5 and 6 regulations (from 39% to 91%). On the other hand, the fleet of light diesel vehicles was renewed less and hence aged more.

The increased EV scenario (4-ELEC) led to a lower renewal of conventional vehicles (diesel and gasoline) and thus to lower rates of vehicles complying with the most recent regulations and of diesel vehicles equipped with DPF. The 5-AIR scenario applied only within the A86 outer ring road and resulted in a lower number of electric vehicles in Île-de-France, but with a higher proportion inside the A86 ring-road, which, combined with an overall reduction in traffic in the city center, makes it "locally" effective.

Figure 3 gives the average light-vehicle composition for Ile-de-France. The share of Euro 5 and 6 regulations (including EVs) increased from 39% in the reference scenario to 80%-90% in the projected scenarios. Light diesel vehicles decreased from 73% to 43% in the petrol scenario (3-PET), 58% in the 4-ELEC, 68% in the 5-AIR scenario (50% within the A86 outer ring road). About 80% of light diesel vehicles were equipped with DPF in the different projected scenarios, against 42% in the reference. Electric vehicles represented 11% in the 4-Elec scenario in Île-de-France, and reached 16% within the area bounded by the A86 in the 5-AIR scenario.

Table 1: Average fleet composition for the scenarios in Île-de-France (main evolution in **bold**)

In % of veh.km, for the different scenarios Vehicles	Categories	1-REF	2-BAU	3-PET	4-ELEC	5-AIR (with traffic reduction)
Light duty vehicles (passenger cars and vans)	Diesel *(incl. hybrids)*	73	73	**43**	**58**	68
	% with DPF	*42*	***80***	*83*	*78*	*79*
	Petrol *(incl. hybrids)*	27	26	**56**	**31**	28
	Electric	0.4	0.4	0.6	**10.9**	**3.7**
	% Euro 5 and 6	*39*	***79***	***91***	*81*	*80*
	% of total traffic	86	86	86	86	84
	of which Pass. Cars	*71*	*71*	*71*	*71*	*69*
Trucks	Diesel	99	99	99	97	98
	Electric	0.1	0.1	0.1	**2.3**	**0.9**
	% Euro 5 and 6	*43*	***83***	*83*	*85*	*84*
	% of total traffic	5.3	5.3	5.3	5.3	5.3
Urban buses and coaches	Diesel	99	99	99	99	99
	Electric	-	-	-	**15**	**6**
	% Euro 5 and 6	*49*	***90***	*90*	*97*	*92*
	% of total traffic	0.7	0.7	0.7	0.7	0.8
Motorized two-wheelers	Petrol	100	100	100	59	80
	Electric	0.0	0.0	0.0	**42**	**18**
	% Euro 5 and 6	*0.0*	***54***	*54*	*54*	*54*
	% of total traffic	7.8	7.8	7.8	7.8	9.4

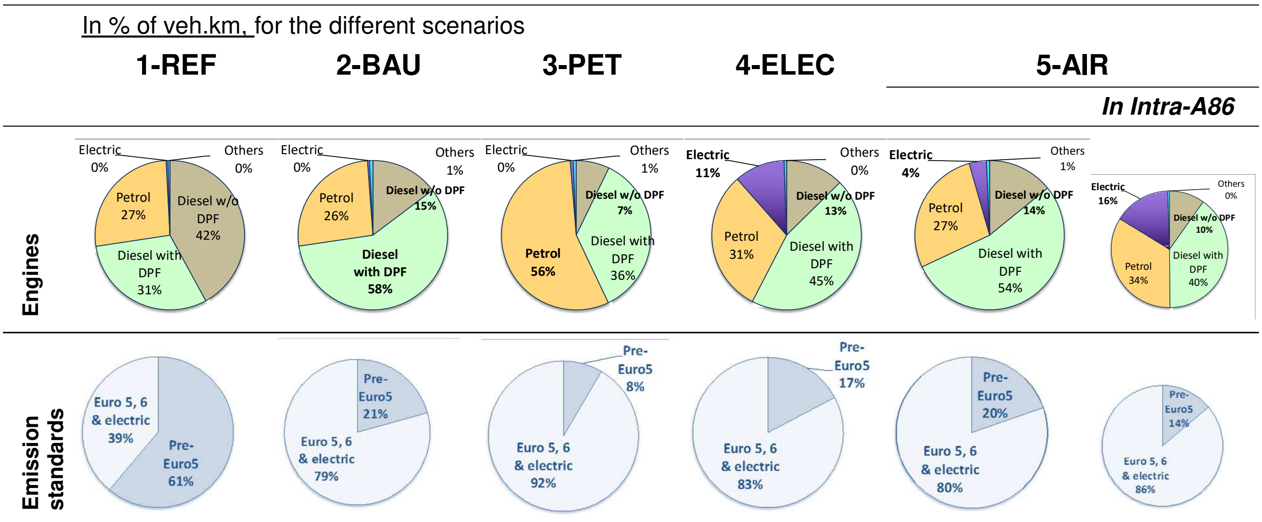


Figure 3: Light vehicle fleet composition in the Île-de-France region and within the A86 outer ring road of Paris, in terms of engine and emission standards

4.2 Pollutant emissions

Pollutant emissions in Île-de-France and road traffic contribution are given in Table 2 for the reference situation (1-REF). Their distribution according to vehicle categories is provided in Table 3. Overall, road traffic contributed significantly to emissions of nitrogen oxide (58% and 78% of total NOx and NO_2 in Île-de-France), BC (54%), and intermediate and semi-volatile compounds (ISVOC) (37%), but less to PM_{10} and $PM_{2.5}$ (20%-25%), and VOCs (11%).

Passenger cars represented 71% of the traffic and accounted for 58% of CO_2 emissions, 44% of VOCs, 46% of NOx, and 42% to 46% of particulates. Light commercial vehicles (vans less than 3.5 tons) accounted for 16% of traffic and emitted 19% of CO_2, 17% of NOx. They contributed more strongly to particulate emissions (36%-40%). Motorized two-wheelers accounted for only around 8% of traffic, but contributed very significantly to VOC (45% of the total). Their contribution to other pollutants was rather limited. Heavy vehicles (trucks, buses and coaches) accounted for only 6% of traffic, but contributed significantly to emissions of CO_2 (20%), NOx (36%), NO_2 (18%) and particulates (12%-16%).

Table 2: Pollutant emissions from all sectors and from road traffic (in tons per year) in Île-de-France for the reference situation (scenario 1-REF)

Total emissions (in $t.yr^{-1}$)	NOx	NO_2	NH_3	VOC	PM_{10}	$PM_{2.5}$	BC
All sectors	78,490	13,682	5,713	82,253	19,038	12,200	2,037
Road traffic	45,216	10,622	508	8,631	3,769	2,993	1,096
Road traffic (in % of total emissions)	*57.6*	*77.6*	*8.9*	*10.5*	*19.8*	*24.5*	*53.8*

Table 3: Distribution of road traffic (in % of veh.km) and pollutant emissions (in % of $t.yr^{-1}$) in terms of vehicles categories in Île-de-France for the reference situation (scenario 1-REF)

	Traffic	Exhaust & evaporation (VOC) emission			Exhaust and non-exhaust emission		
Vehicles		CO_2	VOC	NOx	PM_{10}	$PM_{2.5}$	BC
Passenger cars	70.8 %	57.6 %	43.8 %	45.9 %	42.8 %	45.3 %	46.3 %
Light duty vehicles	15.5 %	18.6 %	5.5 %	17.1 %	40.0 %	35.9 %	35.7 %
Two-wheelers	7.8 %	3.6 %	45.2 %	1.3 %	3.3 %	3.3 %	1.5 %
Trucks	5.3 %	15.0 %	3.5 %	24.2 %	10.7 %	12.3 %	11.7 %
Buses / coaches	0.7 %	5.2 %	1.9 %	11.6 %	3.2 %	3.1 %	4.7 %
Total	5.46×10^4 veh.km	1.13×10^7 tons	8.64×10^3	4.39×10^4	2.93×10^3	3.62×10^3	1.09×10^3

In the reference, 69% of traffic was diesel vehicles (light and heavy), which emitted 75% of CO_2, 92% of NOx, and 96% to 98% of particulates. Gasoline traffic (25% of CO_2) emitted mainly VOCs and NH_3 (86% and 87%) and contributed marginally to particulates (2% to 4%) and NOx (8%).

With regard to emission regulations, 68% of the reference traffic was carried by vehicles complying with Euro 4 (Euro IV) or earlier regulations, which produced 69% to 96% of emissions of the different pollutants. Euro 5 and 6 technologies (V and VI for heavy vehicles) represented 31% of total traffic and contributed much less to emissions (8% of VOCs, 16% of NH_3 and 4% to 6% of particulate pollutants), except for NOx (29%).

Among diesel passenger cars and light commercial vehicles, those equipped with particulate filters accounted for 28% of the distances traveled, but only contributed 1% to 2% of particulate emissions and 5% of NH_3 emissions. However, they were responsible for 30% of NOx emissions.

4.3 Evolution of the traffic emissions with the technology scenarios

Pollutant emissions and traffic in the 2025 scenarios are compared to the 2014 reference situation in Table 4. The 2-BAU scenario, which was almost a business-as-usual progression from diesel with particulate filters, resulted in very sharp reductions in exhaust particulate emissions (-60% to -70% for BC, a compound of fine particles), while reductions were less significant for coarse particles (-30 to -40% for PM_{10}) due to the wear and abrasion contribution. With the regulatory evolution and renewal of vehicles, the emissions of gaseous pollutants also decreased: by 10% for CO_2, 30% for VOCs, 50% for nitrogen oxides, and 36% for NH_3.

The petrol scenario (3-PET) accentuated reductions in NOx (-60%) and exhaust particulate emissions (-74%), but led to a lower reduction in VOCs (-12%) and NH_3 (17%). The 4-ELEC scenario (promotion and increase in electric vehicles in urban areas) had a clear CO_2 advantage (-19% vs -10%). NOx and NH_3 reductions were also very high (-60% and -37%). Particulate emission reductions were slightly higher than those of the 2-BAU scenario, but lower than those of the petrol scenario.

At the Île-de-France scale, the 5-AIR scenario (combining promotion and increase in electric vehicles and reduction in traffic inside the A86) did not offer a significant advantage over the scenarios favouring petrol or electric vehicles. However, emission reductions were markedly increased within the A86 outer ring road of Paris (-71% for NOx instead of -58% in Île-de-France, -75% for BC, -57% for $PM_{2.5}$). This scenario, which included restrictions within a given perimeter, therefore had a definite advantage for the atmosphere over the heavily urbanized and densely populated area inside the A86.

Technological scenarios are compared in Table 5. The petrol scenario led to an increase of 15% in VOC emissions and 30% in NH_3, while it brought further reduction of PM from -10% to -30%. These differences were quite similar inside the A86 and throughout the Île-de-France. The reduction in particulate emissions was more limited with the 4-ELEC scenario (but more marked within the A86). This scenario led to a net reduction in VOC (-25%) and CO_2. Finally, the 5-AIR scenario yielded the strongest benefits to the areas inside the A86: -34% of BC, -38% of nitrogen oxide and about -20% of VOCs, highlighting the benefit of reduced traffic in densely populated areas.

Table 4: Road traffic volume and pollutant emissions in Île-de-France with the 2025 scenarios, compared to the 2014 reference situation

Variations in % relative to the scenario 1-REF (year 2014)	Traffic	Exhaust & evaporation (VOC) emission			Exhaust and non-exhaust emission		
		CO_2	VOC	NOx	PM_{10}	$PM_{2.5}$	BC
Entire Île-de-France region (year 2025)							
2-BAU, diesel, high share of DPF	0.0	-10	-30	-53	-33	-43	-62
3-PET, decline of diesel for petrol	0.0	-9	-12	-62	-40	-52	-74
4-ELEC, increase in EVs	0.0	-19	-42	-62	-36	-47	-66
5- AIR, increase in EVs and traffic reduction	-3.9	-17	-39	-58	-37	-47	-65
Highly populated intra-A86 area (year 2025)							
5- Air, increase in EVs and traffic reduction	-14.5	-34	-47	-71	-47	-57	-75

Table 5: Road traffic volume and pollutant emissions in Île-de-France with the 2025 scenarios, compared to the "business-as-usual" scenario inducing a generalization of diesel particulate filters (2-BAU)

Variations in % relative to the scenario 2-BAU (year 2025)	Traffic	Exhaust & evaporation (VOC) emission			Exhaust and non-exhaust emission		
		CO_2	VOC	NOx	PM_{10}	$PM_{2.5}$	BC
Entire Île-de-France Region (year 2025)							
3-PET, decline of diesel for petrol	0.0	1	15	-19	-11	-16	-31
4-ELEC, increase in EVs	0.0	-10	-25	-18	-5	-7	-11
5- AIR, increase in EVs and traffic reduction	-3.9	-7	-6	-10	-6	-7	-8
Highly populated intra-A86 area (year 2025)							
5- AIR, increase in EVs and traffic reduction	-14.5	-26	-19	-38	-24	-27	-34

4.4 Vehicle fleet renewal effect

From the reference to 2025 scenarios, fleet compositions differed not only in terms of technologies (diesel, petrol, etc.) and their traffic proportions, but also in renewal induced by evolution. So, the 3-PET scenario led to a higher fleet turnover and a higher proportion of Euro 5 and Euro 6 vehicles. The differences in emissions thus included a renewal effect, which can be separated from the technology effect by adjusting the emissions estimation according to similar Euro distributions (Table 6).

For NOx, the benefit was mainly due to the change from diesel to petrol engines, while the renewal effect was opposite between diesel (NOx increase) and petrol (NOx decrease) vehicles. The reduction in exhaust VOCs between 2-BAU and 3-PET scenarios was driven by accelerated renewal of the petrol vehicles, which induced, on the other hand, an increase in evaporative (and total) VOC emissions. For particulates, the benefit of petrol engines was around 55% and 70% of the total effect, the remaining benefit being due to the accelerated renewal.

Table 6: Pollutant emission variations between the 2-BAU and 3-PET scenarios: respective contributions due to diesel to petrol change and to accelerated fleet renewal

Difference (%) in emission (exhaust or total) between scenarios 3-PET (decline of diesel for petrol) and 2-BAU (diesel, high share of DPF)							
(All vehicles - Île-de-France)	NOx	VOCs Exhaust	VOCs Total	$PM_{2.5}$ Exhaust	$PM_{2.5}$ Total	BC Exhaust	BC Total
Total difference	-19.8	-12.4	+15.2	-32.7	-15.8	-40.4	-31.3
Contribution from Euro regulatory change and vehicle renewal							
- Light vehicles - diesel	*+11.4*	*-0.9*	*-0.7*	*-9.1*	*-3.1*	*-18.2*	*-13.3*
- Light vehicles - petrol	*-4.5*	*-17.2*	*-10.1*	*-0.1*	*+0.1*	*-0.1*	*-0.0*
Vehicle renewal total effect	**+6.9**	**-18.1**	**-10.8**	**-9.1**	**-3.0**	**-18.3**	**-13.3**
Net effect due to the diesel-petrol change	**-25.7**	**+5.8**	**+26.0**	**-23.5**	**-12.8**	**-22.1**	**-18.0**

4.5 Evolution of the total emissions with the technology scenarios

The reductions in total emissions (all sectors) through the scenarios were more limited than the reduction in road traffic emissions. The most significant reductions concerned NOx (-35% to -40%) and NO_2 (-47% to -54%), and BC (-36% to -42%) compared to the reference situation. Reductions in particulate emissions were lower (-15 % for $PM_{2,5}$, -20% to -23% for OM, and less than 5% for PM_{10}).

4.6 Evolution of pollutant concentrations

4.6.1 Spatial distribution and evolution of concentrations

Figure 5 shows the annual average concentrations of ozone, $PM_{2.5}$, BC, and of secondary inorganic and organic aerosols over Île-de-France in the reference simulation, as well as the relative differences between the 2-BAU scenario and the reference.

In the reference, O_3 concentrations were lower in Paris and along main roads than over the rest of the Île-de-France. Indeed, O_3 was titrated by the high concentrations of NO in Paris and along the main roads. On the other hand, the average $PM_{2.5}$ concentrations (and other primary particulate compounds) were higher in Paris than in the rest of Île-de-France. BC is an inert compound and emitted mainly by road traffic. The highest BC concentrations were therefore observed in Paris and along the main roads, with concentrations between 0 and 2 $\mu g.m^{-3}$, while concentrations were less than 0.4 $\mu g.m^{-3}$ over most of Île-de-France. However, these were concentrations averaged annually and on grid cells, and thus much lower than those measured at roadside. Average concentrations of primary pollutants, such as BC and secondary pollutants such as O_3 and $PM_{2.5}$, were higher in the northern part of the domain, because of the prevailing meteorology.

Inorganic aerosols are secondary pollutants formed mainly by condensation of nitric acid and ammonia (NH_3) in Île-de-France (in other regions, sulfates may be predominant). Their concentration was relatively uniform over Île-de-France, with concentrations higher than 6 $\mu g.m^{-3}$. Organic aerosols are also largely secondary pollutants. Their concentrations were higher than 2 $\mu g.m^{-3}$ throughout Île-de-France. Higher concentrations were observed in Paris due to anthropogenic emissions of VOCs and ISVOC, as well as near the Fontainebleau Forest (South-West), the Chevreuse High Valley Nature Park (South-East) and the Regional Park of Oise (North of Île-de-France). In the vicinity of these forests, organic matter is formed by oxidation of biogenic VOCs emitted by forests. Oxidized compounds partition on the particles and are therefore partly in gaseous and partly in particulate phase.

Compared to the reference year 2014, all scenarios for 2025 led to quite similar evolution due to the large reduction in emissions. We therefore discuss here only the difference between the 2-BAU scenario and the 1-REF. We will compare 2-BAU and 3-PET later.

The 2-BAU scenario mainly induced a decrease in NOx emissions. The impact on O_3 concentration depends on the chemical regime, which can be inferred from Figure 4. The regime is limited in NOx (low NOx) where the VOC/NOx ratio is higher by a factor of about 8, and the regime is limited in VOC (high NOx), where the VOC/NOx ratio is lower than 8 (Seinfeld and Pandis, 1998). The decrease in NOx emissions by this 2025 scenario led to a slight decrease in O_3 over part of Île-de-France, where the chemical regime was limited in NOx (low NOx). However, where the regime was limited in VOC (high NOx), the NOx reduction induced by the scenario reduced the O_3 titration with NO, leading to an increase of O_3. O_3 increased significantly (up to 27% of annual average) in Paris and along main roads. This increase in O_3 was not a real problem because it occurred in areas of low average concentrations. Nevertheless, it indicates that the 2-BAU scenario (which maintains a high proportion of diesel vehicles) also leads to an increase in oxidants in Paris and along roads, which would lead to increased production of secondary aerosols if precursors (NO_2 and VOC that form SOA) are not reduced.

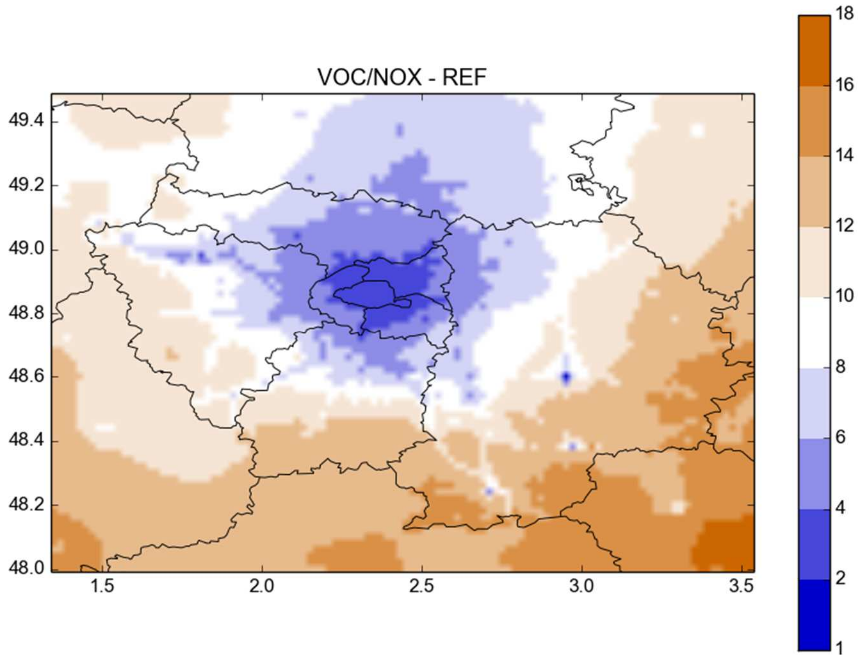
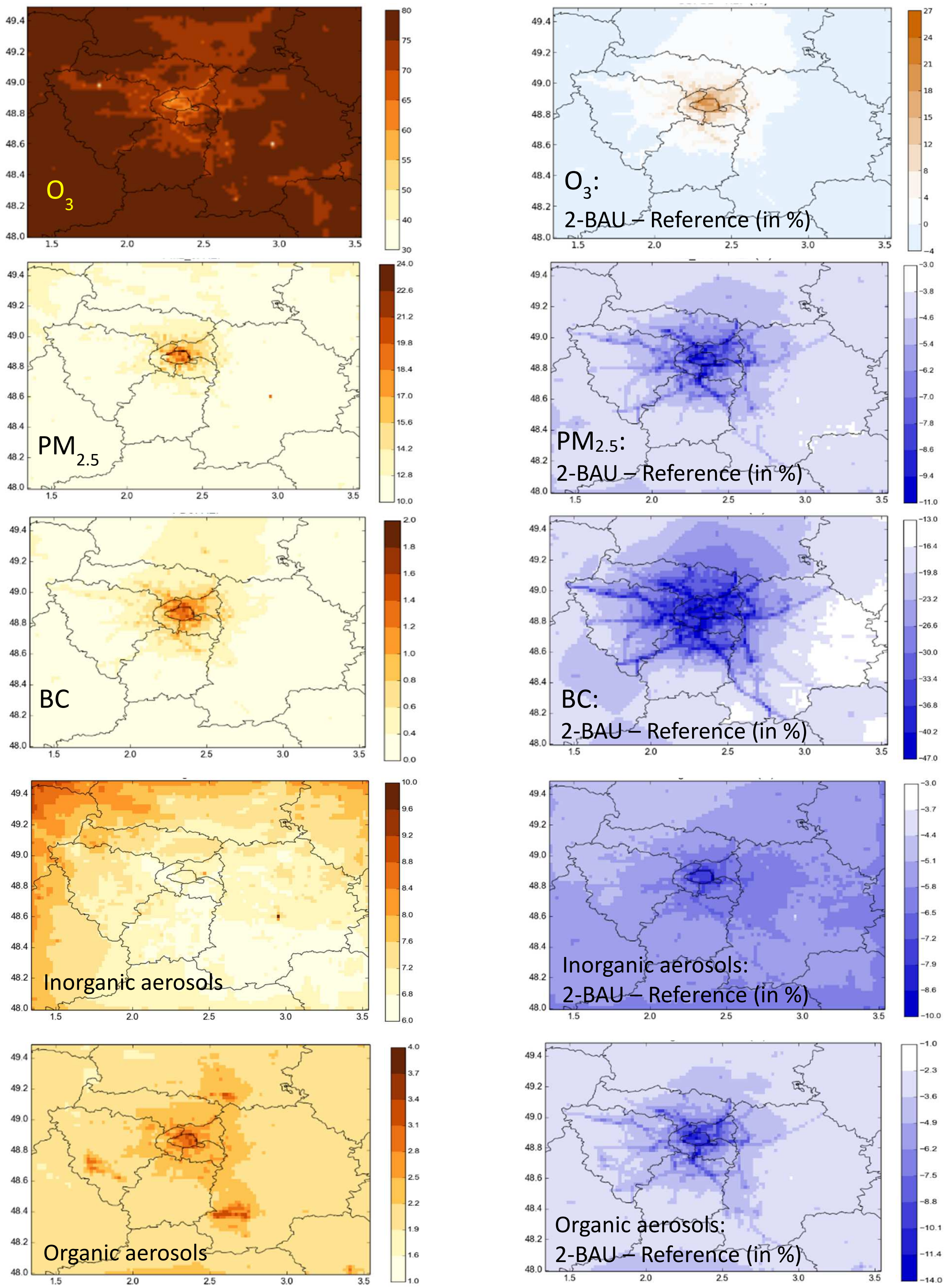


Figure 4 : Determination of chemical regime: VOC/NO_x ratio for the reference simulation (1-REF).



Reference scenario (1-REF, 2014) annual average concentrations

Differential comparison of 2-BAU (diesel, high share of DPF, 2025) *versus* Reference (1-REF, 2014)

Figure 5: Annual average concentrations of pollutants for the 2014 reference situation (left) and impact of the 2-BAU (diesel, with a high share of DPF) scenario in 2025 (right)

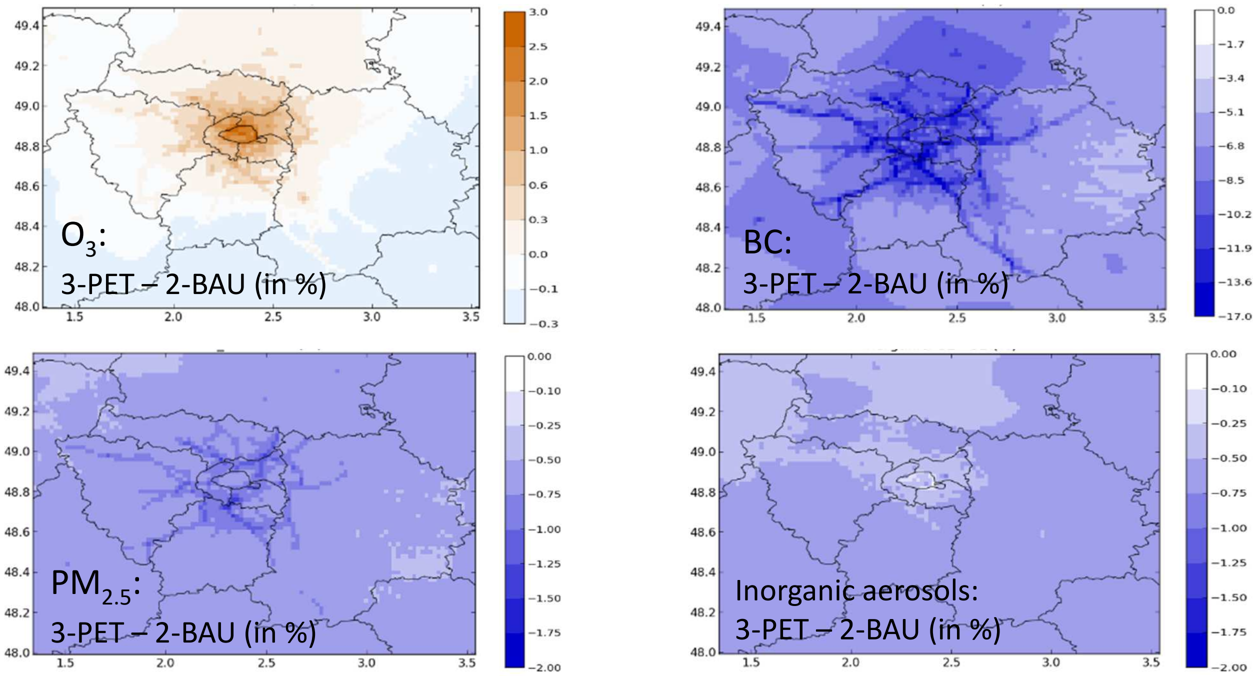
For $PM_{2.5}$, the highest differences between the 2-BAU scenario and the baseline simulation were observed along major highways as well as in Paris. Across the Île-de-France, $PM_{2.5}$ concentrations decreased from 3% to 12%. A strong reduction in BC concentrations (up to -47%) was also observed.

The 2-BAU diesel scenario induced a reduction in inorganic aerosol concentrations of between 3% and 10%. This was due to the decrease in NOx emissions, and thus in concentrations of nitric acid, which is the limiting factor for the formation of ammonium nitrate in Île-de-France. The sharpest decline was in Paris. However, the reduction in inorganic aerosol concentrations was limited (at most 7% on average in Paris), because the increase in oxidants counterbalanced the decrease in NO_2, limiting the decrease in nitric acid induced by the NOx reduction. The reduction in Paris and along main roads was less visible than for $PM_{2.5}$, because $PM_{2.5}$ consists of both secondary compounds, such as ammonium nitrate, and primary compounds, such as BC, which were strongly reduced.

The 2-BAU scenario also led to a reduction in organic aerosol concentrations in Paris along main roads, and near forests and nature parks. The decrease was due to the diminution in ISVOC emissions along main roads, and to the decrease in oxidants (due to reduced NOx emissions) in the vicinity of the forests.

Compared to the 2-BAU scenario (see Figure 6), the 3-PET scenario, with a decline of diesel for petrol engines, induced a slightly larger increase in annual mean O_3 concentrations in Paris (+ 3%) due to a further reduction in NOx emission, whilst VOC concentrations were limited. On the other hand, the 3-PET scenario led to greater reduction in particulate compounds than the 2-BAU scenario.

Thus, the petrol scenario led to a further reduction in $PM_{2.5}$ concentrations, by -1% to -2% in Île-de-France, and a more marked decrease along the main roads around Paris. Additional reductions in BC concentrations were also observed, reaching as much as -17% along main roads.



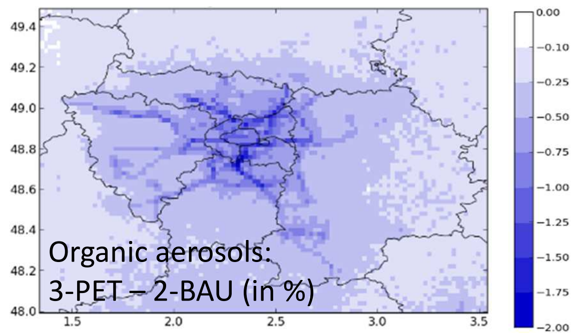


Figure 6: Annual average concentrations of pollutants, differences between the 2-BAU (diesel, high share of DPF) and 3-PET (petrol) 2025 scenarios (3-PET – 2-BAU in %). Note that the scales used in this Figure are different from those of Figure 5, because the differences between the two 2025 scenarios are much lower than the differences between the 2014 reference simulation and each of the 2025 scenarios.

A drop of a few percentage points more for inorganic concentrations was due to the greater decrease in NO_2 emissions in this petrol scenario (3-PET), compared to the 2-BAU scenario. This decrease was slightly lower in Paris and along the Boulevard Périphérique (inner ring road), because oxidant levels were higher in the petrol scenario.

The petrol scenario caused a further decrease in organic concentrations (up to -1.5%, especially along te main roads), due to a larger decline in emissions from ISVOC organic aerosol precursors. However, this decline was more limited in Paris where the scenario induced an increase in oxidant levels.

4.6.2 Concentration statistics

For the reference simulation over Île-de-France, Table 7 shows the average annual concentrations (in $\mu g.m^{-3}$) for each pollutant as well as their standard deviation (spatial variation of the annual concentrations). The standard deviation is large for NO_2 and BC because they are local pollutants mainly emitted by traffic. It is smaller for O_3 and inorganic particles because they are secondary pollutants formed by the interactions of pollutants from different emission sources.

We also defined a threshold or limit (P98, i.e., the 98th percentile of the time series of daily concentrations in each grid cell) to count the number of temporal events for which daily concentration values are higher than this limit, and to assess the evolution of this number of exceedances through the scenarios. This P98 threshold is thus a theoretical short-term concentration limit. It does not correspond to the recommended or authorized limits for health, but enables assessment of events corresponding to high pollution levels, for each pollutant.

Table 7: Statistics of the pollutant concentrations (average concentrations and number of values exceeding the P98 threshold) for the different scenarios compared to the reference

	$PM_{2,5}$	PM_{10}	PM_{10} inorganic	PM_{10} organic	BC	NO_2	O_3
1-REF, reference (year 2014)							
Average concentration (µg.m^{-3})	12.3	13.1	7.0	2.2	0.4	6.7	75.5
Standard deviation (spatial variations)	1.1	1.4	0.3	0.2	0.2	5.3	2.9
P98 threshold in µg.m^{-3}) (i.e. 2% of values exceeding)	27.9	29.9	16.5	6.0	1.3	35.5	126.3
2-BAU scenario (generalization of diesel DPF, year 2025) – compared to 1-REF (year 2014)							
Variation in average concentration (%)	-5.0	-4.8	-5.7	-4.1	-26.8	-40.5	0.6
Variation in the number of values exceeding the P98 threshold (%)	-10.5	-11.2	-16.9	-12.2	-73.0	-84.6	-7.4
3-PET scenario (strong decline in diesel for light vehicles, year 2025) – compared to 1-REF (year 2014)							
Variation in average concentration (%)	-5.6	-5.3	-6.2	-4.5	-32.6	-40.8	0.6
Variation in the number of values exceeding the P98 threshold (%)	-11.8	-11.6	-21.2	-14.2	-77.9	-85.0	-12.4

Except for O_3 (for which an increase of 0.6% was recorded), the average concentrations decreased for each of the scenarios compared to the reference situation. The greatest differences were observed for NO_2 (-41%), BC (-27% for 2-BAU, -33% for 3-PET). For particulate matter ($PM_{2.5}$, PM_{10}) and secondary particulate matter (inorganic, organic), the decrease in mean annual concentrations was lower (between -4% and -6% in the 2-BAU scenario; -4.5% to -6.2% in the 3-PET scenario).

Although the average concentration in O_3 increased, high concentrations - i.e., occurrences exceeding the P98 threshold - decreased by 7% for the 2-BAU, and 12% in the 3-PET scenario.

For NO_2 and BC, the decrease in occurrence of high concentrations was much stronger. It reached -85% for NO_2 and -73% for BC in the 2-BAU scenario. The reduction was slightly higher in the 3-PET scenario (-95% for NO_2 and 78% for BC). Finally, for particulate matter, the reduction in exceedance events was more limited. This was similar to what was observed for the average value. Still, the reduction was significant: from -11% to -17% in the 2-BAU scenario, and -12% to -21% in the petrol scenario.

Overall, future scenarios more strongly reduced occurrence of exceedance of short-term thresholds (estimated here through P98), than the annual average concentrations, and that is true for all pollutants.

Comparing the scenarios 3-PET (promoting petrol vehicles) and 2-BAU (maintaining a high proportion of diesel),, the statistics were quite close. However, we observed a slight advantage for the petrol scenario, the differences with the baseline being always greater than those observed in the 2-BAU scenario.

The increase in annual O_3 was slightly higher in the petrol scenario, but high concentrations were more strongly reduced. Indeed, the O_3 increase was mainly a feature of Paris and its periphery (where the chemical environment was limited in VOC) due to higher VOC emissions in the petrol scenario. Higher O_3 concentrations mainly occurred outside Paris (low-NOx chemical environment), where the petrol scenario was more favorable due to lower NOx emissions.

Concentrations in BC (inert pollutant) were also more reduced by the petrol scenario due to stronger reduction in BC emissions.

For organic and inorganic secondary aerosols, the 3-PET scenario led to slightly larger decreases in concentration. For organics, the high concentrations along main roads and in Paris decreased more than with the 2-BAU scenario, although the concentrations in O_3 and oxidants were higher. The decrease was due to lower emissions of ISVOC, intermediate semi-volatile compounds. These were supposed to be proportional to emissions of organic particles (OM) which were lower with the petrol scenario. The same conclusions held when simulations were performed by estimating ISVOC emissions from VOC emissions instead of from OM emissions (Sartelet et al. 2018).

For inorganics, the advantage of the 3-PET scenario was due to lower NOx emissions and concentrations, inducing a decrease in nitric acid (HNO_3) concentrations. Inorganics in Ile-de-France are mainly composed of ammonium nitrate, the formation of which is limited by HNO_3 concentrations (Sartelet et al., 2007). Hence the decrease in NOx and thus in HNO_3 concentrations induces a reduction in inorganic concentrations.

5 Conclusions

Simulations of pollutant emissions and concentrations over the Île-de-France region under different technological scenarios demonstrated a strong decrease in road traffic emissions by 2025 compared with 2014 (-30% to -60% according to the different pollutants). This was due to generalization of particulate filters on diesel vehicles and large renewal of the vehicles fleet to comply with the most recent regulations (Euro5 and 6) (2-BAU scenario). A scenario favoring petrol engines (3-PET) would induce a stronger renewal of the fleet and reduce more particulate and NOx emissions, but less VOC and NH_3 compared to the business-as-usual scenario.

Both 2-BAU and 3-PET 2025 scenarios led to lower annual average concentrations compared to the 2014 reference baseline, especially for NO_2 (-54% to -60%) and BC (-47% to -56%), and more strongly reduced the number of high concentration events. For other compounds ($PM_{2.5}$, secondary pollutants), reductions were more limited due to the influence of other activity sectors and atmospheric chemistry. Ozone concentrations might even increase in some urban locations and periods, but remained low in these cases.

The differences between the 2025 scenarios themselves were smaller. For PM emissions and concentrations, the petrol scenario (3-PET) was slightly more favorable than the 2-BAU one, across all pollutants. Differences were marked for primary particles from traffic (BC) and less for secondary compounds ($PM_{2.5}$, organic and inorganic fractions). The difference was also marked for NO_2. The petrol scenario advantage was mainly due to lower emissions (-80% of $PM_{2.5}$, -60% of BC), partially linked to the accelerated fleet renewal with this scenario (higher share of Euro 5 & 6).

A more ambitious scenario (5-AIR) combining the promotion of electric vehicles and a traffic reduction in the densely populated urban area inside the A86 outer ring road of Paris would bring supplementary benefits for all emissions in this zone (-34% for BC, -20% to -44% for gaseous pollutants). Although concentrations were not simulated for that scenario, a definite advantage could be expected, due to the combination of vehicle technologies and traffic reduction for the most urbanized and densely populated area.

Beyond these results, this study demonstrated the value of exhaustive simulation for the evaluation of traffic evolution scenarios and technological options. Pollutant emissions and concentrations were estimated as well as their geographical distribution (in relation to population exposure), taking into account other sectors of activity and emission sources that had a considerable influence on concentrations.

A critical and systematic analysis of the approach (André et al., 2019) clarified the methodological choices and identified limitations: fragility of certain hypotheses, invariance of emissions from other sectors, insufficient knowledge of the real emission factors of recent engines and pollution control technologies, emissions of unregulated pollutants, precursors of secondary pollutants and semi-volatile organic compounds, insufficient spatial scale to simulate proximity concentrations.

Different ways were identified for exploring these boundaries:

- Simulation of more radical scenarios (e.g., 100% petrol) and sensitivity analysis to different assumptions;
- Studies at finer resolutions and the broadening of the assessment to include exposure and health impacts;
- The development of more comprehensive prospective scenarios integrating the evolution of all sectors of activity, demographic and mobility trends.

This study also highlighted the need for coordination of public policies in favor of air quality (and climate) due to the contributions of the different sectors of activity. As regards road traffic, reducing traffic in densely populated areas appeared to be an important lever for reducing impacts, alongside technological and regulatory developments.

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