vehicles

MDPI

Article

Assessment of Urban Traffic Emissions in Relation to Vehicle Fleet Structure

Alexandru-Constantin Oprica *, Dragoș Tutunea, Ilie Dumitru and Andretti Ciungu

Faculty of Automotive, Technological and Mechanical Engineering, University of Craiova, 200512 Craiova, Romania; dragos.tutunea@edu.ucv.ro (D.T.); ilie.dumitru@edu.ucv.ro (I.D.); andretti.ciungu@yahoo.com (A.C.)
* Correspondence: alexandru.oprica@edu.ucv.ro

Abstract

This paper analyzes pollutant emissions generated by urban road traffic in relation to the structure of the vehicle fleet. The study uses COPERT in order to quantify the contribution of different vehicle categories based on fuel type and emission standard under representative urban driving conditions. Fleet composition was derived from vehicle registration statistics, disaggregated by fuel type and emission standard, while annual mileage was allocated per vehicle category using an age-dependent activity algorithm reflecting the relation between vehicle age and average traveled distance. The methodology combines vehicle fleet distribution data with category-specific emission factors to estimate total emissions for a baseline scenario. Based on this, alternative scenarios are developed, including accelerated electrification of the fleet and fleet renewal through the replacement of older vehicles with those complying with more stringent emission standards. The main scope of the study is the comparative assessment of these strategies, all derived from the same baseline, rather than the provision of a precise inventory of current emission levels, in order to evaluate their relative effectiveness. The results highlight the significant influence of fleet composition on urban emission levels and show that emission reductions depend strongly on both the rate of electrification and the removal of high-emitting, older vehicles. Electromobility adoption is the proper solution for tailpipe CO_2 mitigation, while a significant reduction in pollution can be achieved by fleet renewal.

Keywords: vehicles; average-speed model; fleet activity; electromobility adoption; fleet renewal

1. Introduction

COPERT 5.10.1 (Calculations of Emissions from Road Transport) is a software model developed by the European Environment Agency for estimating macroscale vehicle emissions based on European data using mileage, vehicle fleet composition, driving speed, air humidity and temperature. It has been widely used in most European countries for compiling national emission inventories, but also for emission modeling at the street level. Specifically, this requires relying on the average speed and travel distance provided by a traffic model or measurements for each period, road segment and vehicle category, and then applying the COPERT speed-dependent functions to each of these road segments [1–4].

In addition to vehicle characteristics, emission levels in urban areas are strongly influenced by traffic volume and its temporal variation. Traffic is a dynamic phenomenon, varying between peak and off-peak periods, weekdays and weekends, and different periods of the year. Previous research has highlighted the variability of road traffic [5,6], which

Check for updates

Received: 2 September 2026
Revised: 3 October 2026
Accepted: 13 October 2026
Published: 25 October 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

is particularly relevant for urban emission evaluations, where fleet composition, vehicle activity and traffic conditions should all be considered. While it is unable to capture traffic dynamics continuously throughout the day, the COPERT Tier 3 methodology [7] uses an average speed-based approach that differentiates between peak-hour and off-peak-hour speed values.

COPERT includes several vehicle categories (passenger cars, light commercial vehicles, heavy-duty vehicles and buses) with their respective technologies. Each category is further split into specific segments. The fuels that can be considered in the model are petrol, diesel, biodiesel, LPG and CNG, and hybrid and electric vehicles can also be included. The emission levels of different vehicles depend mostly on their emission standards, which are covered by COPERT, ranging from pre-1970s technologies up to the newest (Euro 7) [7].

The emissions are calculated as the product of the travel distance and the emission factors (Equation (1)), which are continuous functions of speed derived from representative driving cycles [8]. These emission factor functions are defined for each pollutant k and each vehicle category c [3].

$$E_{k,c} = D_c \times F_{k,c}(V_c) \quad (1)$$

$E_{k,c}$—the total emissions for a trip;
$F_{k,c}$—the unitary emission factor [g/km] of pollutant k and vehicle category c;
D_c—the total travel distance [km];
V_c—the mean speed for vehicle category c [km/h].

A study that compared the integration of macroscopic traffic models with two emission estimation approaches found that COPERT performed better in urban environments [9]. The emission factors of Australian vehicles were estimated using the COPERT model and then verified through a tunnel emissions study [10]. COPERT was also used to analyze the potential of combining autonomous vehicles, electric vehicles and park-and-ride systems to reduce urban transportation emissions through various policy scenarios [4]. In [2], COPERT was applied to calculate CO_2eq emissions from bus fleets, emphasizing the impact of fleet modernization and P&R (Park&Ride) infrastructure on reducing greenhouse gases. CO (carbon monoxide), CO_2 (carbon dioxide), NO_x (nitrogen oxides) and PM (particulate matter) emissions of heavy-duty diesel passenger buses were calculated using the COPERT model in Hainan Province, with the conclusion that stricter standards and electrification would achieve significant emission cuts [11]. It was utilized to validate Madrid's emission predictions in a study where vehicle activity data were obtained from a traffic simulation model [12] and to determine the composition of the Hungarian vehicle fleet for 2020, 2030 and 2050 in a scenario-based analysis of transport energy consumption, emissions and monetary implications for Budapest [13]. Another study related to Madrid implemented COPERT for road emission calculations in a 10-year analysis of vehicle fleet evolution [14]. The results show that the city became cleaner in terms of NO_x and $PM_{2.5}$ due to new Euro standards, low-emission zone policies, hybrid adoption and bus fleet modernization, but CO_2 emissions remain largely unimproved, highlighting the need for electrification and low-carbon fuels. In [15], the authors used COPERT for tank-to-wheel (TTW) emissions calculation within a well-to-wheel (WTW) model for comprehensive CO_2 analysis at the national level for Ireland. It was also applied to obtain long-term projections of road transport-related emission rates for pollutants and greenhouse gases (GHGs) in St. Petersburg [16]. According to the authors, the emissions are projected to decline despite the increase in the vehicle fleet, and the greatest impact on emission reduction would come from fleet modernization and stricter standards. The COPERT-based models have the advantage of not being data-intensive and can be utilized even if a limited number of road traffic variables are known [17]. The related methodology includes emission factors for a

considerable number of vehicle types and provides estimates for a wide range of pollutants and GHGs.

While the reviewed literature provides a comprehensive overview of the possibilities of using COPERT for emission estimation and scenario analysis, the authors consider that there are a few gaps that have been only partially addressed. The software offers the possibility of including multiple categories of vehicles, but most studies focus on just one category: private vehicles [4], taxis [18], buses [2,11] and passenger cars [15]. The studies were conducted at the city level [2,4,13,14,16], regional level [11] or national level [15,19], focused on a specific network [3,9], corridor [17] or roundabout [12], or were used for methodological validation [10,20]. Among the studies in the first three groups (more relevant from the fleet composition point of view), the only ones considering a multi-category analysis are [13,14,16,19]; however, Refs. [16,19] do not employ a Tier 3 speed-dependent approach. In [13], COPERT is applied only for projected fleet composition, and [14] assesses the evolution of emissions without providing future scenarios. A number of articles test different future fleet compositions in diverse scenarios [2,4,11,15,16,18,19], but, as far as we know, none has adopted a complete Tier 3 methodology for analyzing several vehicle types. The present study addresses these gaps by applying Tier 3, speed-differentiated COPERT modeling to a complete urban fleet (passenger cars, light commercial vehicles and buses), distinguishing between urban peak and off-peak driving conditions, across three scenarios (Business-as-Usual, Accelerated Fleet Renewal, Accelerated Electromobility Adoption) derived from the 2026 activity baseline. In addition, annual mileage is allocated across Euro-standard categories using an age-dependent function, an approach documented in emission inventory practice but, to the authors' knowledge, not previously applied for this purpose within the reviewed COPERT literature.

2. Methodology

The scope of this article is to assess urban traffic pollutant emissions in the municipality of Craiova under current conditions and across different fleet projection scenarios for 2030. The year 2030 was chosen (rather than a more distant future year) in order to minimize potential errors in estimating fleet trends caused by uncertainties arising from European and national policies regarding the automotive industry, while still capturing the effects of Euro 7 vehicle market penetration. The year 2026 serves as the baseline for the analysis, while three scenarios are considered for 2030:

- Business-as-Usual (BAU2030), assuming that the vehicle fleet follows the current market trends;
- Accelerated Fleet Renewal (AFR2030), representing the replacement of the oldest vehicles with newer, less polluting alternatives;
- Accelerated Electromobility Adoption (AEA2030), assuming faster adoption of electric vehicles than in the BAU2030 scenario (with the share of hybrids remaining the same as in BAU2030).

The calculation of annual urban pollutant emissions using COPERT 5.10.1 software is carried out using a model based on environmental data, fleet configuration, vehicle fleet activity and fuel data (Figure 1).

For the COPERT calculations, the Tier 3 methodology, which requires information on the vehicles in the fleet, fleet activity and circulation, was used to estimate emissions based on vehicle activity. For this purpose, the kilometers traveled, the vehicle types, the corresponding Euro standards and the average driving speeds are utilized. The methodology estimates the sum of hot emissions and cold emissions (Equation (2)). Hot emissions are the most common because they occur when the engine is functioning at its normal operating temperature, but the inclusion of cold emissions is important because emission

levels for some pollutants are much higher and strongly dependent on ambient conditions during the warming-up phase [7]. Hot emissions depend on several factors such as distance traveled, speed, vehicle age, power and engine size (Equation (3)). Cold emissions are calculated as additional emissions relative to those expected from warmed-up engines, by applying a factor determined by the climatic conditions, ambient temperature and the time required to warm up the vehicle [1,4]. COPERT also offers the possibility of separating the emissions according to road type [7,17]: rural, urban and highway driving conditions (Equation (4)). Since this study focuses only on the urban circulation, in our study, the total overall emissions are equal to the total urban emissions.

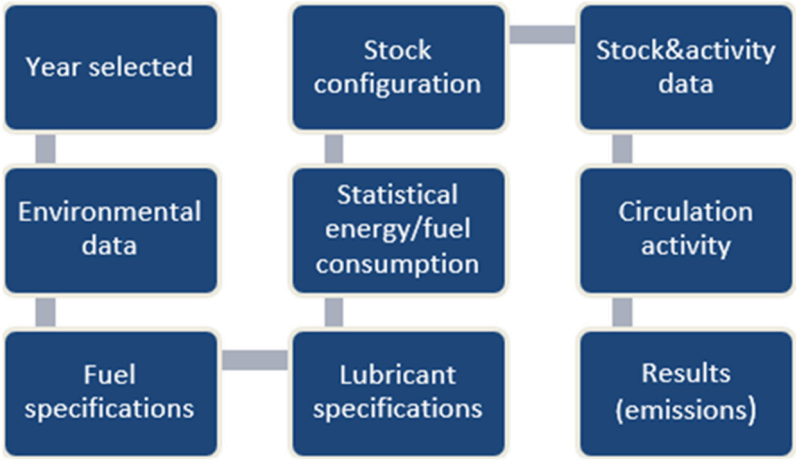


Figure 1. COPERT model estimation procedure [1,4,8].

$$E_T = E_H + E_C \quad (2)$$

E_T—total emissions [g] of the pollutant;
E_H—emissions (g) during hot (stabilized) engine operation;
E_C—emissions (g) during cold (thermally transient) engine operation.

$$E_{H_{i,j,k}} = N_j \times D_{j,k} \times e_{H_{i,j,k}} \quad (3)$$

$E_{H_{i,j,k}}$—hot exhaust emissions of the pollutant i (g) produced during the studied period by vehicles of emission standard j driven on roads of type k;

N_j—number of vehicles of emission standard j in operation;

$D_{j,k}$—distance traveled per vehicle [km/veh] on roads of type k by vehicles of emission standard j;

$e_{H_{i,j,k}}$—emission factor [g/km] for pollutant i, produced by vehicles of emission standard j on roads of type k.

$$E_T = E_{Rural} + E_{Urban} + E_{Highway} \quad (4)$$

3. Case Study—Craiova

Craiova, the capital of Dolj (a county situated in the south-west of Romania), has an area of 81.41 km^2 and a population of approximately 270,000 inhabitants. It is one of the largest cities in Romania and an important road and railway junction, as well as a major center of socioeconomic activity in the region [21] (Figure 2). The data for humidity and temperature for the municipality of Craiova were estimated based on the information from [22] (Figure A1).



Figure 2. Craiova road network.

According to the transport demand model implemented in the Craiova PMUD (Sustainable Urban Mobility Plan), the number of daily trips will reach almost 1,500,000 in 2030 (excluding transit and freight traffic), of which 60% will be motorized (car and public transport). The average length of a car trip will be slightly more than 5.5 km, and the average distance covered by public transport will be around 6 km [23]. As of 31 December 2025, the Dolj County vehicle fleet comprised a total of 340,951 vehicles, of which 273,755 were passenger cars, 35,480 were light goods vehicles and 1305 were buses and minibuses [24]. According to [23], the motorization index (*Mot_index*) in the city of Craiova was estimated to reach a value of 0.471 (471 passenger cars/1000 inhabitants) in 2026, which, based on the current number of inhabitants ($N_{inhabitants}$), has resulted in a total of approximately 127,170 passenger cars (Equation (5)). The number of registered buses in circulation was set to 122 [21]. Due to a lack of data, for light commercial vehicles, a weighting coefficient was derived as the arithmetic mean of two indicators: the share of economic agents located in the Municipality of Craiova relative to Dolj County (55.7%) and the share of passenger cars registered in Craiova ($N_{passenger_cars(city)}$) relative to the total passenger car fleet of Dolj ($N_{passenger_cars(county)}$). The resulting coefficient was applied to the fleet of light commercial vehicles in the county ($N_{light_com_veh(county)}$) in order to estimate the corresponding number operating in the city ($N_{light_com_veh(city)}$) (Equation (6)).

$$N_{passenger_cars(city)} = N_{inhabitants} \times Mot_index \quad (5)$$

$$N_{light_com_veh(city)} = 0.5 \times \left(0.56 + \frac{N_{passenger_cars(city)}}{N_{passenger_cars(county)}}\right) \times N_{light_com_veh(county)} \quad (6)$$

Based on the data reported in [24] regarding the distribution of propulsion technologies within the passenger car fleet at the county level, a proportional allocation method was applied to estimate the corresponding vehicle numbers for the Municipality of Craiova (Equation (7)). The same formula was used in the case of light commercial vehicles. While the electric propulsion is expected to have a slightly higher share in urban areas, no

adjustment factor was further applied because, in a tank-to-wheel (TTW) analysis, electric vehicles have zero emissions for most pollutants.

$$N_{passenger_cars(city),k} = N_{passenger_cars(county),k} \times \frac{N_{passenger_cars(city)}}{N_{passenger_cars(county)}} \quad (7)$$

$N_{passenger_cars(city),k}$—the number of passenger cars of propulsion type k in the city

$N_{passenger_cars(county),k}$—the number of passenger cars of propulsion type k in the county

To classify vehicles into classes needed for COPERT calculations according to segment and fuel type [7], the data available at the national level [25] were used, processed and adapted to the values calculated for the propulsion categories in the city, as presented in Figure A2. This resulted in 25 vehicle classes defined by category, segment and fuel (Figure A3) for passenger cars and 9 classes for light commercial vehicles. Each of these vehicle classes was further divided into vehicle types according to Euro standards from non-Euro to Euro 6d/e, based on the age distribution of the fleet [24] (Equation (8)) (Figure A4). The municipality's bus fleet has undergone a renewal process in recent years and consists of 122 vehicles (the operating fleet), of which 68 are electric and 38 are Euro 6 diesel. In total, 231 vehicle types were integrated into the model according to the COPERT classification: 162 passenger car types (Tables A1–A4), 63 light commercial vehicle types (Table A5) and 6 bus types (electric, Euro 4, Euro 5 and Euro 6 standard urban buses).

$$N_{i,j,k,l(city)} = N_{i,(city)} \times \frac{N_{i,j(nat)}}{N_{i(nat)}} \times \frac{N_{i,k(city)}}{N_{i(city)}} \times \frac{N_{i,l(city)}}{N_{i(city)}} \quad (8)$$

$N_{i,j,k,l(city)}$—the number of vehicles of category i, segment j, fuel type k and Euro standard l in the city;

$N_{i(city)}$—the number of vehicles of category i in the city;

$N_{i(nat)}$—the number of vehicles of category i at the national level;

$N_{i,j(nat)}$—the number of vehicles of category i and segment j at the national level;

$N_{i,k(city)}$—the number of vehicles of category i and fuel type k in the city;

$N_{i,l(city)}$—the number of vehicles of category i and Euro standard l in the city.

For the third term on the right-hand side of the equation, the national values were used when the city values for a certain fuel were not available.

To determine the mean activity (km/year) for passenger cars, the number of all daily trips (including all modes of transport) in the Craiova growth pole for 2026 was interpolated based on the values for 2014 and 2030 and was adjusted to the municipality level. The modal distribution for 2026 (also interpolated) was applied to calculate the number of daily trips for this vehicle category. Using that value, the average distance traveled [23] and the number of vehicles, the average annual urban distance traveled by a typical passenger car was obtained (Equation (9)).

$$D = \frac{K \times \left(d_t_{2014} + \frac{12 \times (d_t_{2030} - d_t_{2014}}{16}\right) \times S \times 365 \times d}{N} = 6284 \text{ km/year} \quad (9)$$

D—mean urban distance traveled by a typical passenger car;

K—adjustment factor based on the employment share of the municipality in the growth pole (0.87);

d_t_{2014}—total daily trips in 2014 (1,350,000) [23];

d_t_{2030}—total daily trips in 2030 (1,480,000) [23];

S—share of passenger cars in total daily trips in 2026 (30.5%);

d—average trip length for passenger cars (5.7 km);

N—number of passenger cars in the fleet (127,170).

In a study assessing how vehicle age influences annual mileage and its impact on air pollutant emissions [26], the authors concluded that assuming constant mileage throughout a vehicle's lifespan leads to overestimation, whereas using age-dependent mileage functions provides more accurate estimates. The findings of this study were used to derive and adapt the relative activity factors associated with vehicle age in order to establish the distribution of vehicle activity across emission standards (Figure 3). Since the reference predates the introduction of Euro 6, the Euro 5 relative activity factor was assigned to the newer passenger cars. A segment-specific normalization coefficient (p) was calculated for each passenger car segment (Mini, Small, Medium and SUV) to account for the different distributions of emission standards while preserving the same average annual urban mileage (Equation (10)). The mean activity associated with each emission standard was obtained from the normalization value and the relative age-dependent factor (Equation (11)).

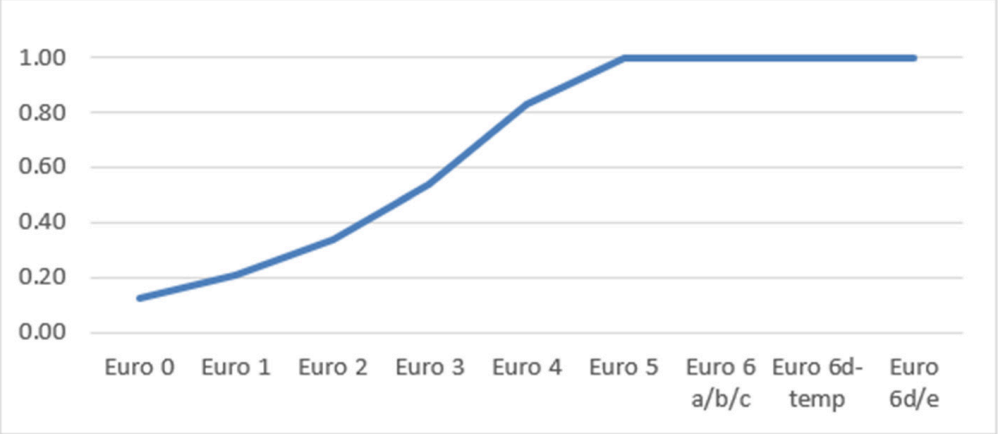


Figure 3. The relative age-dependent factor (f) for passenger car mileage allocation by Euro standards.

$$p_k = \frac{d_{base_avg} \times \sum N_{ik}}{\sum N_{ik} \times f_i} \quad (10)$$

p_k—the normalization coefficient for segment k;
d_{base_avg}—average base distance (6284 km/year);
N_{ik}—the total number of passenger cars belonging to Euro standard i and segment k;
f_i—the relative factor for the Euro standard i.

$$D_{ik} = p_k \times f_i \quad (11)$$

D_{ik}—mean distance traveled by a passenger car of Euro standard i and segment k.

Due to the lack of data on urban vehicle activity in the municipality for light commercial vehicles, an average annual base urban mileage of 7000 km was assumed, representing a conservative estimate, approximately 10% higher than the value calculated for passenger cars. Relative activity factors associated with each emission standard were derived from an age-dependent mileage profile adapted from [27] (Figure 4). A normalization coefficient (q) was introduced to ensure that the weighted average mileage of the fleet remained equal to the assumed category average (Equation (12)). The mean activity associated with each emission standard was obtained from the normalization value and the relative age-dependent factor (Equation (13)).

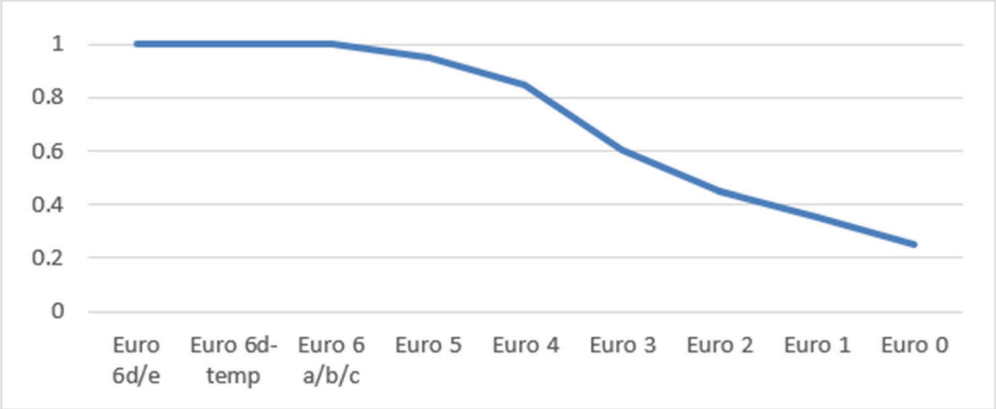


Figure 4. The relative age-dependent factor (f) for light commercial vehicle mileage allocation by Euro standards.

$$q = \frac{d_{base_avg} \times \sum N_j}{\sum N_j \times f_j} \quad (12)$$

d_{base_avg}—average base distance (7000 km/year);
N_j—the total number of light commercial vehicles belonging to the Euro standard j;
f_j—the relative factor for the Euro standard j.

$$D_j = q \times f_j \quad (13)$$

D_j—mean distance traveled by a light commercial vehicle from Euro standard j.

Regarding the bus fleet, the mean vehicle activity was calculated based on the information provided in [21], using the annual fleet mileage (vehxkm) and the number of active buses (Equation (14)). In this case, no differentiation according to emission standards was applied.

$$D_b = \frac{D_{f_b}}{N_b} \quad (14)$$

D_b—mean distance traveled by a bus;
D_{f_b}—the annual fleet mileage (veh*km);
N_b—the number of active buses.

The circulation data required by a COPERT Tier 3 model are the speed and the mileage share [18]. According to [23], the peak hour occurs in the afternoon, between 3:00 PM and 6:00 PM, representing approximately 7.3% of the daily traffic volume. However, Urban Peak circulation conditions are not limited to the single highest hour and are associated with at least two intervals (if not three) of increased traffic demand: 1–2 h in the morning, 2–3 h in the late afternoon and possibly another 1–2 h around midday. The circulation patterns reported in [23] indicate that traffic levels on the main urban corridors remain relatively high throughout most of the daytime. Considering this, together with the values adopted in other COPERT-based studies [18,28], a 50% share was assigned to each of the Urban Peak and Urban Off-Peak conditions. Since average driving speed is a direct input to the COPERT calculation, supplementary field measurements were performed on representative urban routes in Craiova using a GPS-based mobile application. The measurements covered different urban driving conditions and were used to characterize the typical speed levels associated with Urban Peak and Urban Off-Peak circulation. Examples of the recorded speed profiles are provided in Figures A6–A11 in Appendix A. The resulting representative speeds were assigned separately to Passenger Cars and Light Commercial Vehicles for the Urban Peak and Urban Off-Peak conditions. In the absence of measurements for

buses, lower speeds were assumed to account for the additional delays associated with scheduled stops.

For the BAU2030 scenario, the passenger car and light commercial vehicle fleets were updated according to the market trends in terms of vehicle segments, propulsion systems, emission standards and new registrations [29,30]. The forecasted 2030 motorization index for passenger cars in Craiova is 0.481 (481 passenger cars/1000 inhabitants), which results in a total number of 129,870 passenger cars. For passenger cars, the share of SUVs was assumed to increase slightly (based on recent sales trends), while the proportions of the remaining segments were adjusted accordingly. In addition, the propulsion system distribution was updated to reflect the relatively slow penetration of electric vehicles. According to the current trend [24], the shares of electric and hybrid vehicles in the fleet in 2030 are projected to be 1% and 9%, respectively (Figure A5). The fleet of non-electric propulsion vehicles was adjusted to match the new composition (Equation (15)). Euro 7 vehicles were introduced, and Euro 0 and Euro 1 vehicles were assumed to be completely phased out, while the shares of Euro 2, Euro 3 and Euro 4 vehicles were gradually reduced. The light commercial vehicle fleet was assumed to follow the same growth rate as the passenger car fleet. Furthermore, the mean annual activity associated with each emission standard was recalculated to reflect the projected fleet composition (Tables A6–A10) and the age-dependent relative factors were updated (Figure 5). The bus fleet was assumed to remain the same as the baseline scenario, while circulation activity was kept unchanged across all scenarios.

$$N_{i,j,2030} = \frac{N_{i,j,2026} \times k_{i,2030} \times N_{2030} \times (N_{i,2030} - (N_{el,2030} - N_{el,2030,no_trend})}{k_{i,2026} \times N_{2026} \times N_{i,2030}} \quad (15)$$

$N_{i,j,2030}$—the estimated number of passenger cars belonging to segment i and propulsion type j in 2030;

$N_{i,j,2026}$—the number of passenger cars belonging to segment i and propulsion type j in 2026;

$k_{i,2030}$—the estimated share of segment i in the passenger car category in 2030;

N_{2030}—the estimated number of passenger cars in 2030;

$N_{i,2030}$—the estimated number of passenger cars belonging to segment i in 2030;

$N_{el,2030}$—the estimated number of electrified vehicles in 2030 (electric + hybrids);

$N_{el,2030,no_trend}$—the estimated number of electrified vehicles in 2030 (electric + hybrids) without the growth factor;

$k_{i,2026}$—the share of segment i in the passenger car category in 2026;

N_{2026}—the number of passenger cars in 2026.

The BAU2030 scenario serves as the baseline for the other alternative future scenarios. The Accelerated Fleet Renewal (AFR2030) scenario assumes the accelerated replacement of older vehicles (Tables A11–A15), resulting in the complete phasing-out of Euro 0–3 passenger cars and Euro 0–2 light commercial vehicles, together with a 50% reduction in the Euro 4 passenger car fleet and the Euro 3 light commercial vehicle fleet relative to the 2026 baseline. For the bus fleet, all Euro 4 buses are replaced by Euro 7 vehicles, while half of the Euro 5 fleet is also renewed. When expressed as a share of the total passenger car fleet, the application of these renewal rules assumed by the authors is equivalent to an additional renewal of 14.3% relative to BAU2030. The shares of hybrid and electric vehicles remain identical to those in the BAU2030 scenario, isolating the effect of internal combustion fleet renewal from electrification. In contrast, the Accelerated Electromobility Adoption (AEA2030) scenario assumes a significantly higher adoption rate of battery electric vehicles (BEVs) compared with conventional and hybrid vehicles, primarily affecting the composition of newly added vehicles rather than the retirement rate of older conventional vehicles

(Tables A16–A20). The assumed 7% battery electric vehicle (BEV) share of the fleet in AEA2030 represents a deliberately aggressive acceleration scenario. For context, EU-wide modeling projects an average fleet share of 16% by 2030, but Eastern European countries with fleet profiles similar to Romania's, characterized by high second-hand vehicle import rates and long average vehicle lifespans, are projected to reach lower shares: 10% (Poland) and 6% (Bulgaria) only by 2035 [31]. Given Romania's comparable estimated fleet survival parameters, the 7% share assumed for AEA2030 substantially exceeds typical regional adoption trajectories, reflecting its explicit framing as a strong policy-intervention scenario rather than a conventional projection.

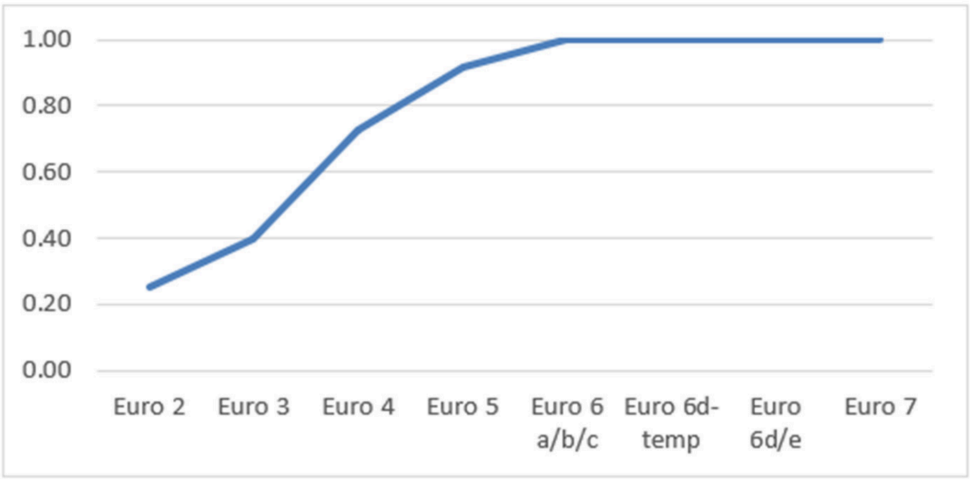


Figure 5. The relative age-dependent factor (f) for passenger car mileage allocation by Euro standards in 2030.

The methodological workflow implemented to obtain the emission results can be summarized as follows:

1. The baseline 2026 fleet was established and disaggregated by vehicle category, fuel type and Euro standard.
2. The annual vehicle activity was determined for each category. The annual mileage of passenger cars and light commercial vehicles was distributed among Euro standard categories using age-dependent activity factors, while bus activity was determined from the available fleet mileage data.
3. The urban circulation was divided between Urban Peak and Urban Off-Peak traffic conditions. A mileage share of 50% was assigned to each, while the corresponding average driving speeds for passenger cars and light commercial vehicles were determined from field measurements. Lower values were assumed for buses to account for the delays caused by the scheduled stops.
4. Based on the 2026 baseline, three fleet scenarios for 2030 were constructed (BAU2030, AFR2030 and AEA2030), according to the information presented in the previous section and summarized in Table 1.
5. The environmental conditions, fleet composition, vehicle characteristics, annual mileage and circulation activity were introduced into the COPERT scenarios. For each scenario, emissions were calculated for the considered vehicle categories, propulsion types and Euro standards under the defined urban circulation conditions.
6. Finally, the calculated emission values were aggregated by vehicle category, fuel type and Euro standard. The resulting values were subsequently used in the next section to compare the scenarios in terms of CO_2, NO_x, CO, $PM_{2.5}$ and NMVOC (non-methane volatile organic compounds) emissions.

Table 1. Summary of the simulated scenarios.

Scenario	Fleet Composition	Fleet Renewal	EV Adoption	Activity
Baseline2026	Current 2026 fleet	Current age structure	Current share	2026 activity
BAU2030	Projected 2030 fleet	Normal renewal	Projected share (1%)	Projected activity
AFR2030	Faster replacement of older vehicles	Accelerated renewal (14.3% relative to BAU2030)	Same as BAU2030	Same as BAU2030
AEA2030	Higher penetration of EV	No accelerated retirement	Accelerated EV adoption (7% share)	Same as BAU2030

4. Discussion of Results

The total emissions were calculated at vehicle category, fuel type and Euro standard levels for the four considered scenarios: Baseline2026, BAU2030, AFR2030 and AEA2030. The Baseline2026 scenario illustrates the estimated emissions for the baseline year (2026), while BAU2030 reflects the projected emissions in 2030 based on the continuation of current fleet composition trends. The comparison between the BAU2030, AFR2030 and AEA2030 scenarios offers valuable insights into the impact of two alternative policy approaches (accelerated fleet renewal and accelerated electromobility adoption) on tailpipe carbon emissions and air pollution.

Passenger cars account for the largest share of CO_2 emissions exceeding 160,000 tonnes, of which approximately 143,000 tonnes are generated during hot engine operation and almost 18,000 tonnes during cold operation. They are followed by the light commercial vehicles which emit more than 30,000 tonnes, whereas the buses are responsible for just over 3000 tonnes due to the high degree of fleet renewal (Figure A12). Regarding the contribution of fuel types to total passenger car CO_2 emissions, gasoline (petrol) and diesel clearly dominate because of their large share in the fleet. The Urban Peak emissions are higher than the Urban Off-Peak emissions due to suboptimal traffic conditions (Figure A13).

More than 80% of total CO emissions are generated by the gasoline vehicles, with 71% being associated with the passenger cars and 11% with the light commercial vehicles (Figure A14). Figure A15 shows a relatively even distribution of emissions among vehicles of different Euro standards, with only 10% separating the top five contributors. One relevant observation is that the vehicles older than Euro 4 account for almost half of passenger car CO emissions (48%), despite having a significantly smaller share of the fleet.

The diesel vehicles are by far the largest contributors to NO_x emissions, accounting for 90% of the total, while the gasoline vehicles are responsible for only 10%. Diesel passenger cars account for the highest share (59%) and the 54 diesel buses account for 2% (Figure A16). A noteworthy aspect is that the diesel light commercial vehicles are responsible for 29% of the total NO_x emissions although they represent just under 11% of the fleet. This can be explained by the fact that many light commercial vehicles belong to older Euro standards—the pre-Euro 4 vehicles account for almost half of the category's emissions and Euro 4 vehicles generate a quarter of them (Figure A17). The $PM_{2.5}$ emissions are mostly associated with diesel passenger cars (60%), followed by diesel light commercial vehicles and gasoline passenger cars, each accounting for 19% (Figure A18). The dominant contribution of diesel vehicles to NO_x and $PM_{2.5}$ emissions is consistent with the findings of [32]. Passenger cars comprise the category that generates most of the NMVOC emissions, with gasoline vehicles being the largest contributors (Figure A19). An interesting aspect is that cold-engine emissions predominate among passenger cars, while hot-engine emissions

dominate among light commercial vehicles (probably because the longer distances traveled daily result in a lower share of kilometers driven with a cold engine). The evaporative component is almost exclusively associated with the gasoline vehicles.

The BAU2030 scenario projects minor reductions in CO_2 emissions for the passenger car and light commercial vehicle fleets due to the small increase in the share of electrified vehicles, especially hybrid passenger cars, while the bus fleet was assumed to retain the same structure so its contribution is the same (Figure 6). While the diesel and petrol passenger cars are still predominant in 2030, their numbers were assumed to decrease slightly, with some of them being replaced by hybrids, which is reflected in the total emissions by fuel type (Figure 7). The small effect of fleet evolution on CO_2 emissions is also documented in [14], which reports a 7–8% reduction over 10 years. The authors attribute this primarily to the growth in vehicle size and mass under newer Euro standards, which offsets the efficiency gains.

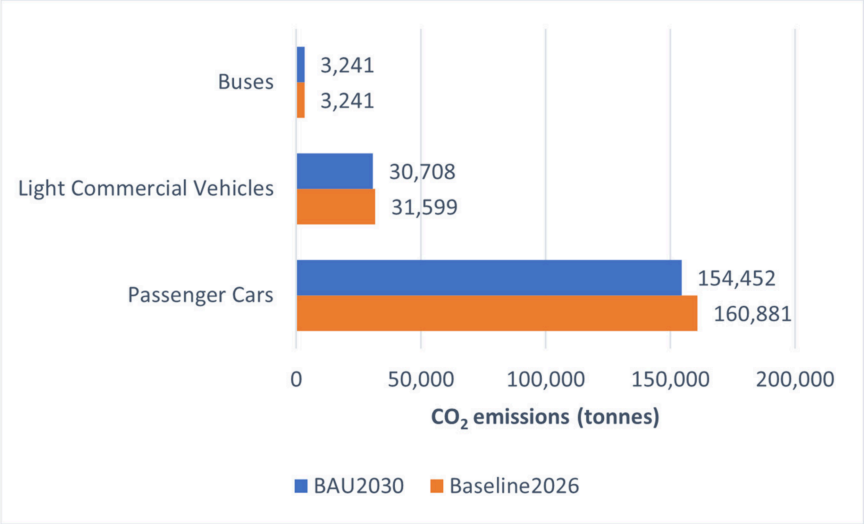


Figure 6. CO_2 emissions (t) by category (Baseline2026 vs. BAU2030).

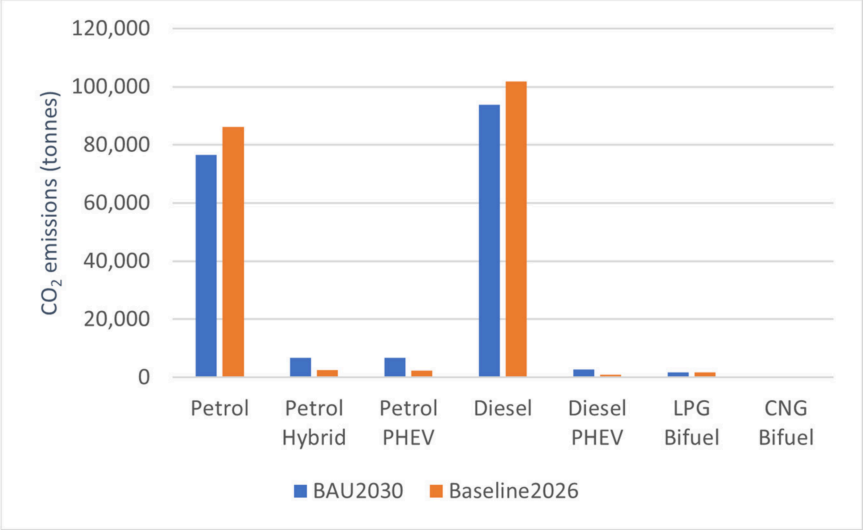


Figure 7. CO_2 emissions (t) by fuel type (Baseline2026 vs. BAU2030).

NO_x emissions in the BAU2030 scenario decrease considerably (almost 33%) for the passenger cars due to the replacement of some of the older diesel vehicles with newer technologies (Figure 8). The improvement in the light commercial vehicle category is much

smaller because the fleet is very old and difficult to replace quickly. Figure 9 shows how the contribution of Euro 5 and older vehicles to NO_x emissions is reduced in the case of passenger cars and light commercial vehicles, while the Euro 6 and Euro 7 vehicles generate relatively smaller amounts. $PM_{2.5}$ emissions produced by the diesel vehicles, which represent the largest source, decrease by a third in the BAU2030 scenario compared to the current scenario (Figure 10). The mitigation of NO_x and $PM_{2.5}$ due to fleet modernization and the implementation of new standards is also highlighted in [14], which reports a reduction of over 40% for both pollutants, while in [16], the projection shows a decrease in $PM_{2.5}$ emissions by a factor of 2, but the NO_x levels were expected to remain roughly the same (most probably due to the age of the studied fleet and the increasing number of vehicles in the fleet). CO emissions are reduced considerably in the BAU2030 scenario compared to the current situation, with the gasoline passenger car category recording a decrease of approximately 60% (Figure 11). As observed for the other pollutants, the improvement is significantly more pronounced for passenger cars than for light commercial vehicles. Additionally, NMVOC emissions from petrol vehicles are reduced by more than 50%, because of the much higher emission factors associated with non-Euro vehicles (Figure 12). The pronounced mitigation of CO and NMVOC due to fleet modernization is consistent with [16], which reports reductions by factors of 3 and 2, respectively.

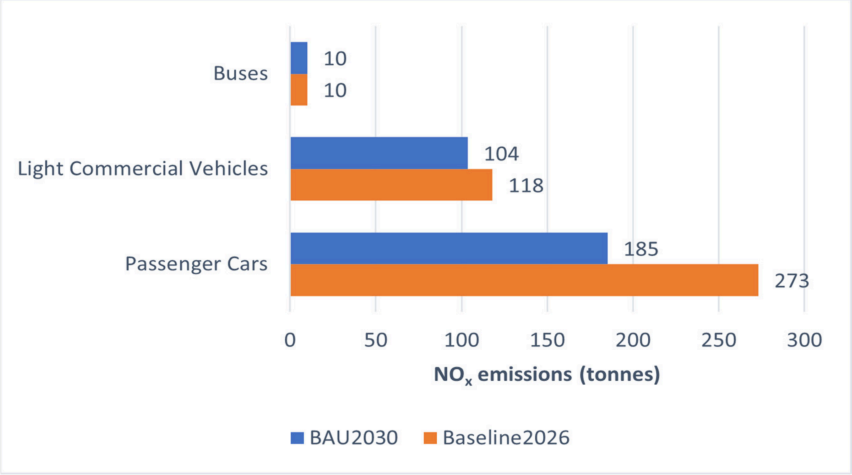


Figure 8. NO_x emissions (t) by category (Baseline2026 vs. BAU2030).

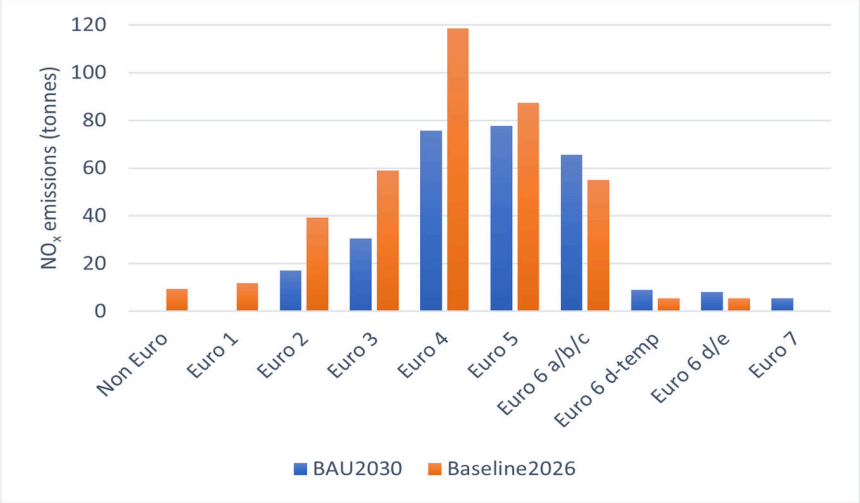


Figure 9. NO_x emissions (t) by Euro standard (for passenger cars and commercial vehicles) (Baseline2026 vs. BAU2030).

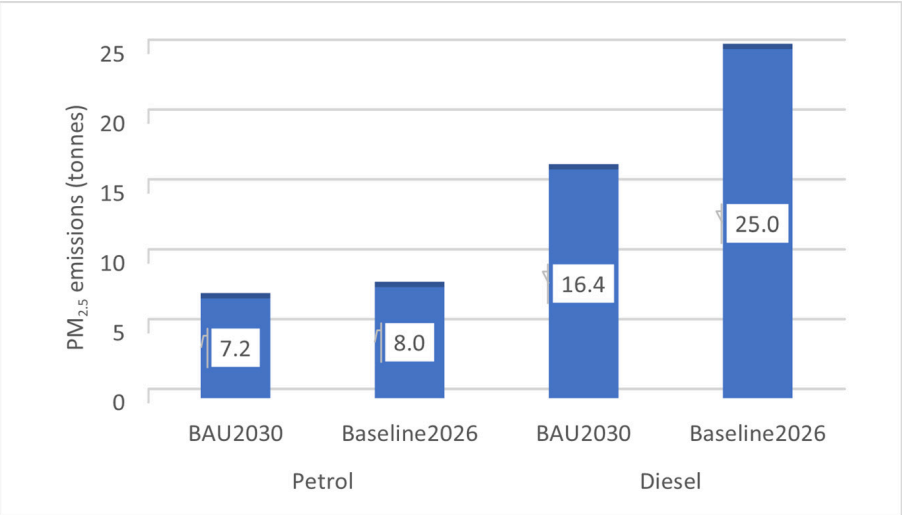


Figure 10. $PM_{2.5}$ emissions (t) for diesel and petrol fuels (Baseline2026 vs. BAU2030).

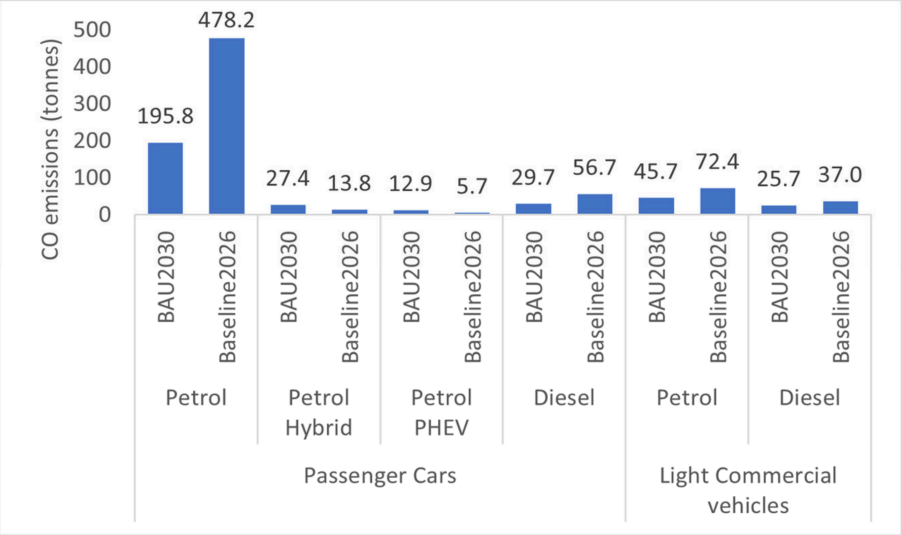


Figure 11. CO emissions (t) by category and fuel (Baseline2026 vs. BAU2030).

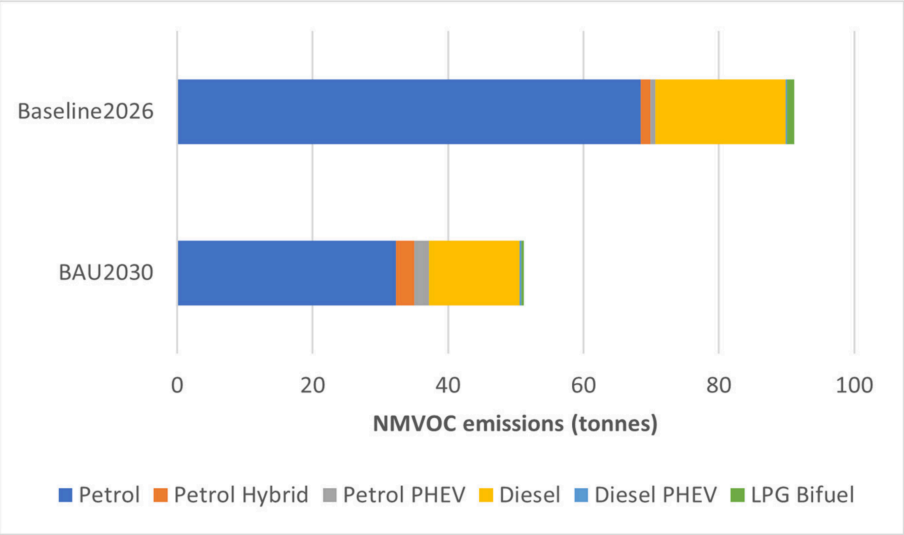


Figure 12. NMVOC emissions (t) by fuel (Baseline2026 vs. BAU2030).

The AEA2030 scenario results in a reduction in passenger car CO_2 emissions of approximately 7% compared to BAU2030 (Figures 13 and 14), a value that is directly related to the assumed 7% share of electric vehicles within the passenger car fleet. The results suggest the need for electrification in order to achieve a substantial decrease in tailpipe CO_2 emissions, which is in accordance with the findings of [11,14]. The inversely proportional relationship between the CO_2 emissions and the share of electric vehicles ensures a high level of predictability regarding the reduction in tailpipe carbon emissions resulting from the implementation of this strategy. The nature of this scenario meant that the light commercial vehicle and bus fleets were assumed to undergo only minor changes; thus, the improvements over BAU2030 are insignificant in those segments.

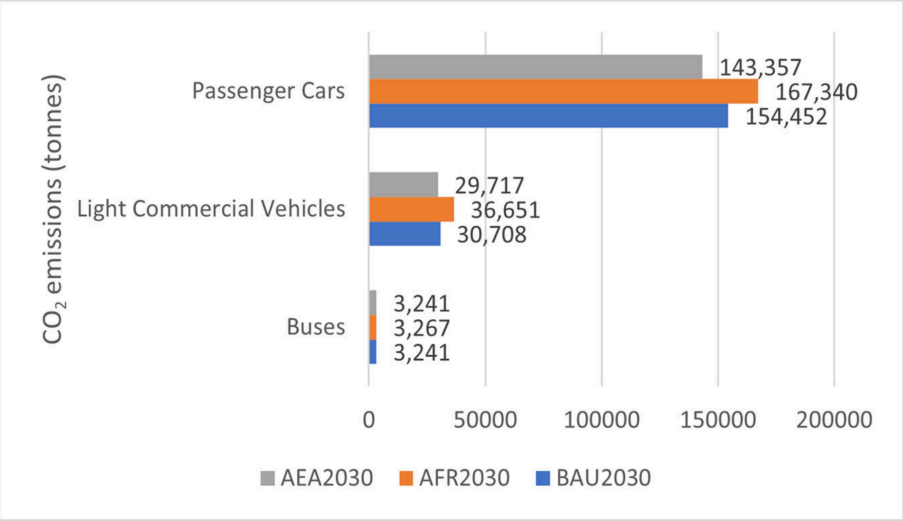


Figure 13. CO_2 emissions (t) by category (BAU2030 vs. AFR2030 vs. AEA2030).

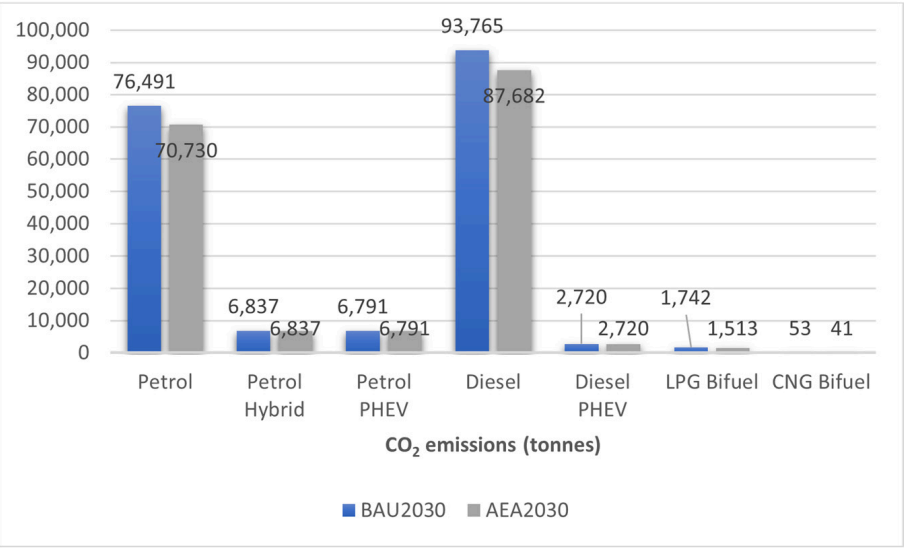


Figure 14. CO_2 emissions (t) by fuel (BAU2030 vs. AEA2030).

The slight increase in total CO_2 emissions in the AFR2030 scenario compared to BAU2030 (Figure 13) is attributable to the COPERT methodology. In this case, COPERT does not use dedicated emission factors and CO_2 is calculated from fuel consumption with the carbon mass balance method [7]. Since annual mileage is age-dependent [26], a fleet renewal (such as the one implemented in the AFR2030 scenario) increases the average distance traveled per vehicle, because the newer vehicles are associated with higher annual

mileage. In the absence of fuel consumption differentiation by Euro standard, this increase in the mean distance traveled translates into higher total CO_2 emissions.

Of all the 2030 scenarios, AFR2030 shows the greatest reduction in NO_x emissions (10.7% compared to BAU2030 and 8.5% compared to AEA2030) because of the strategy of replacing older vehicles (the highest emitters), while the AEA2030 scenario is mostly focused on the newer vehicles in the fleet and has a limited effect on the older ones. The reductions for passenger cars and light commercial vehicles are approximately 8–10%, while the replacement of all Euro 4 buses and half of the Euro 5 buses with new technologies results in a 40% reduction for the bus category (Figure 15). Despite the higher emissions associated with newer Euro standards due to the larger number of Euro 6 and Euro 7 vehicles in the fleet, this increase is more than offset by the phase-out of the Euro 2 and Euro 3 vehicles, together with the reduction in the number of Euro 4 vehicles, leading to an overall decrease (Figure 16). The beneficial effect of fleet renewal on NO_x emissions is supported by the 42% reduction presented in [14] over a 10-year period, compared to 26% in BAU2030 and 34% in AFR2030 in this study (over a 5-year period).

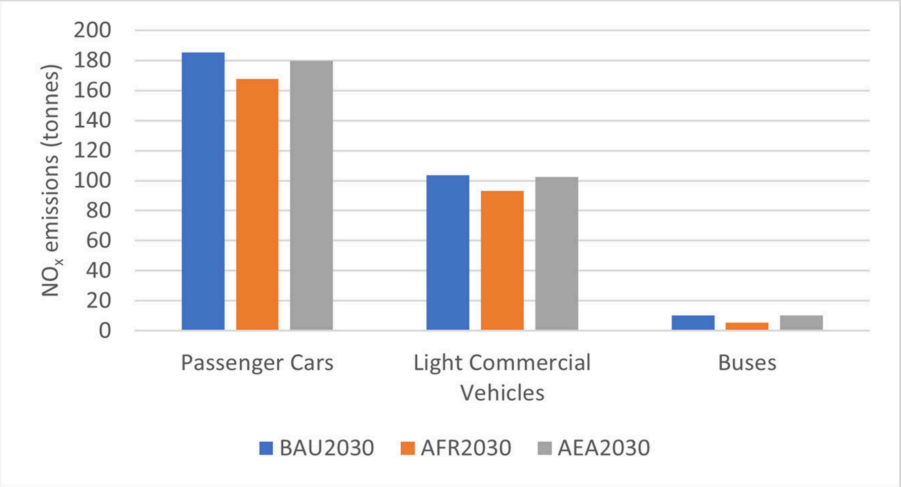


Figure 15. NO_x emissions (t) by category (BAU2030 vs. AFR2030 vs. AEA2030).

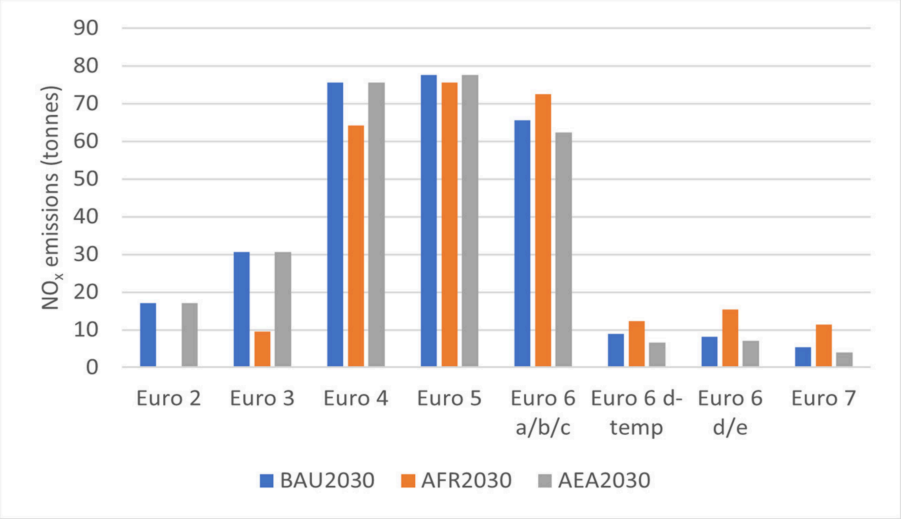


Figure 16. NO_x emissions (t) by Euro standard (passenger cars and light commercial vehicles) (BAU2030 vs. AFR2030 vs. AEA2030).

As in the NO_x assessment, the AFR2030 scenario results in the largest reduction in CO emissions due to the elimination of the older vehicles from the fleet and their replacement

with newer, less polluting ones. Figures 17 and 18 show a shift from the older to the more recent Euro standards in their contributions to total CO emissions in AFR2030. The slight increase in emissions associated with Euro 6 and Euro 7 passenger cars is more than offset by the elimination of Euro 2 and Euro 3 vehicles and the reduction in the number of Euro 4 vehicles. Overall, the AFR2030 scenario decreases CO emissions from passenger cars complying with pre-Euro 5 standards by 63 tonnes compared to BAU2030 and AEA2030, while the AEA2030 scenario provides reductions of 12 tonnes compared to BAU2030 and 29 tonnes compared to AFR2030 for Euro 6 and Euro 7 standards (Figure 17). A similar pattern is observed for the light commercial vehicle category, where the reduction is as pronounced as for the passenger cars. This occurs despite the fact that Euro 4 vehicles are retained and Euro 3 vehicles are only reduced by half, reflecting the current older age structure of the light commercial vehicle fleet (Figure 18).

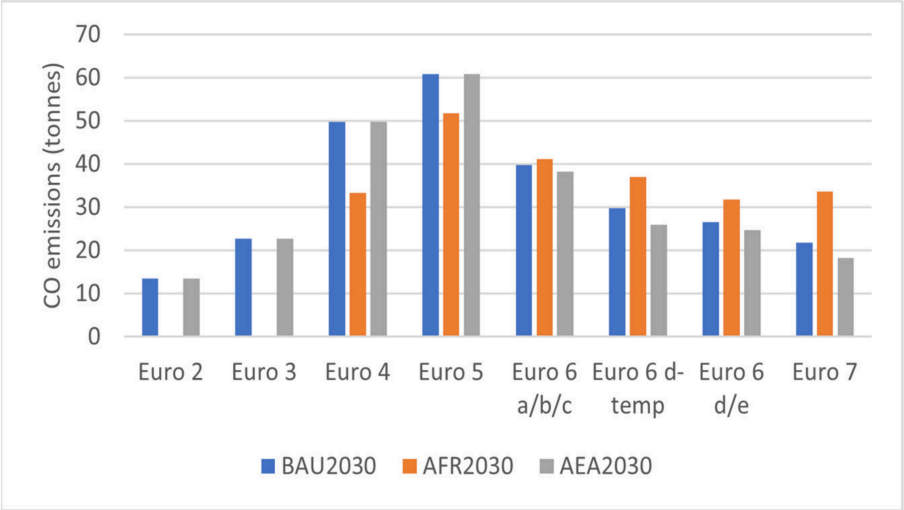


Figure 17. CO emissions (t) by Euro standard for passenger cars (BAU2030 vs. AFR2030 vs. AEA2030).

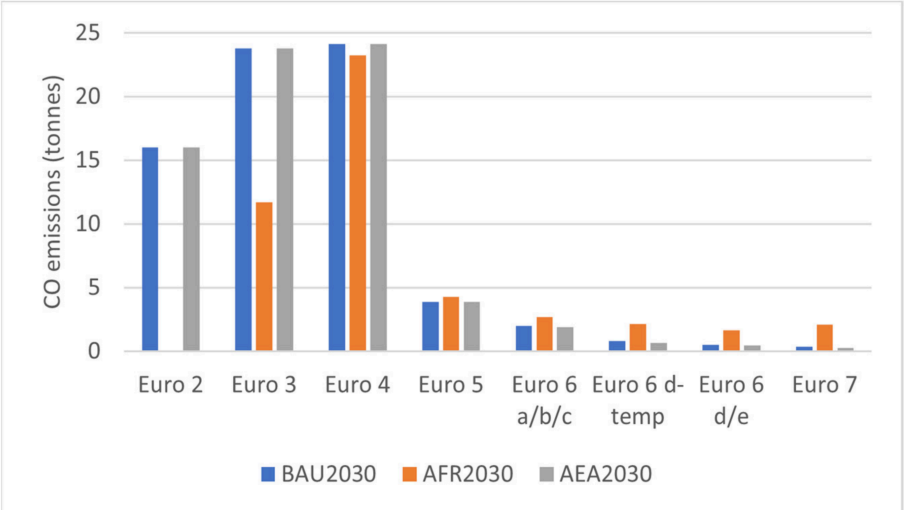


Figure 18. CO emissions (t) by Euro standard for light commercial vehicles (BAU2030 vs. AFR2030 vs. AEA2030).

The differences in $PM_{2.5}$ emissions among the 2030 scenarios are rather modest, with the AFR2030 scenario providing a 12% reduction in emissions from diesel vehicles (the largest contributors) compared to BAU2030. The slight increase in gasoline-related emissions observed in AFR2030 may be interpreted as the combined effect of the changes in fleet

composition and vehicle activity. The AEA2030 scenario offers the best result for petrol vehicles, but the retention of older vehicles in the fleet results in a worse outcome for diesel vehicles compared to AFR2030 (Figure 19). Furthermore, as the share of electric vehicles in the fleet increases, their contribution to total $PM_{2.5}$ emissions should not be neglected. The decreases in NMVOC emissions achieved in AFR2030 and AEA2030 scenarios compared to BAU2030 are limited and substantially lower than those achieved by BAU2030 compared to Baseline2026 because the differences between COPERT emission factors for different Euro standards are considerably smaller than those between non-Euro and Euro-standard vehicles (Figure 20).

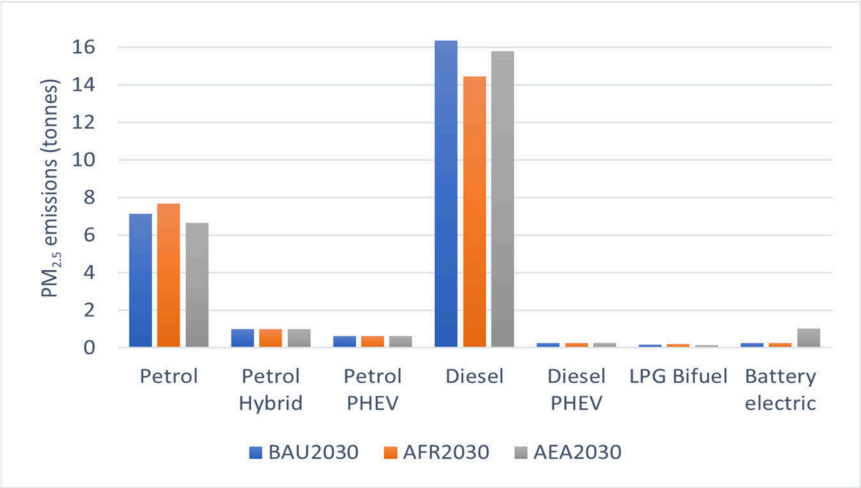


Figure 19. $PM_{2.5}$ emissions (t) by fuel (BAU2030 vs. AFR2030 vs. AEA2030).

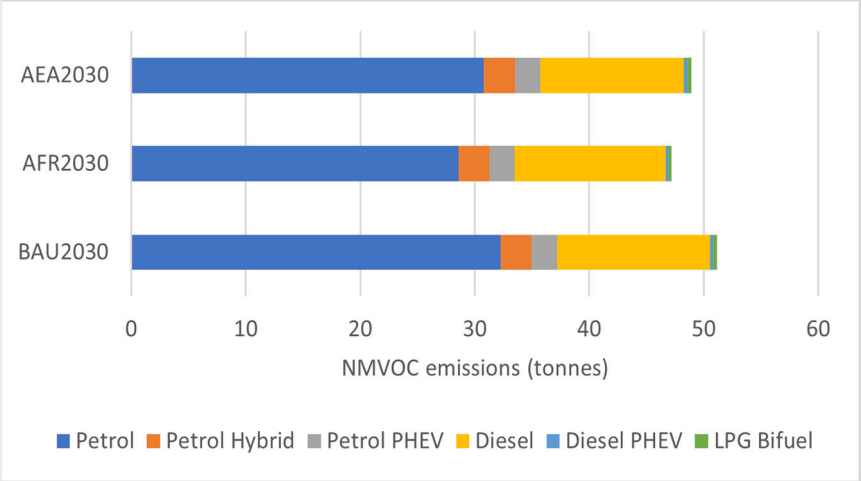


Figure 20. NMVOC emissions (t) by fuel (BAU2030 vs. AFR2030 vs. AEA2030).

As in [14,16], the fleet modernization and new Euro standards lead to a decrease in emissions (in all three scenarios) despite the increase of the motorization index. The finding that the AFR2030 scenario offers the greatest reduction in all pollutants except CO_2 can be explained by the importance of removing the oldest, high-emitting vehicles, as also highlighted in [18]. Within this modeling framework, newer Euro standards alone do not significantly reduce CO_2 emissions, a conclusion supported by the limited improvement obtained in the BAU2030 scenario and by the results of [14]. Fleet electrification (implemented in the AEA2030 scenario) delivers the most consistent TTW decarbonization outcome.

5. Sensitivity Analysis

Given that certain model inputs were assumed or estimated by the authors, a sensitivity analysis was conducted to evaluate their impact on CO_2 and NO_x emissions, focusing on two parameters: the average mileage of the light commercial vehicles (LCVs) and the average travel speed for each of the studied categories.

The sensitivity analysis of light commercial vehicle (LCV) activity (±15% around the 7000 km/year baseline) shows that LCV emissions scale proportionally with mileage for both pollutants in all scenarios. Total fleet emissions change by approximately ±5.2% for NO_x and ±2.5% for CO_2, reflecting the LCV contribution in BAU2030 (35% and 17%, respectively). The absolute values should therefore be regarded as indicative. In contrast, the relative differences between scenarios are stable, varying by 0.5 percentage points at most, and the ranking, which is independent of the LCV activity level, is unchanged (Table 2).

Table 2. Results for the sensitivity analysis of LCV activity effect on emissions (scenario variation).

Pollutant		Base	LCV + 15%	LCV − 15%
CO_2	AFR vs. BAU	+9.9%	+10.2%	+9.7%
	AEA vs. BAU	−6.2%	−6.2%	−6.3%
NO_x	AFR vs. BAU	−11.7%	−11.7%	−11.7%
	AEA vs. BAU	−2.2%	−2.1%	−2.2%

The sensitivity analysis of average urban speed (±5 km/h for passenger cars and LCVs, ±3 km/h for buses, applied to both peak and off-peak conditions) shows that absolute emissions vary substantially with speed, reflecting the speed dependence of COPERT emission functions—approximately 18–20% for CO_2 and 15–17% for NOx between the higher and lower speed cases (Table 3). Despite this, the relative differences between scenarios remain stable (less than 0.2 percentage points for CO_2 and 1 percentage point for NO_x in the AFR2030-BAU2030 difference) and their ranking remains unchanged (Table 4).

Table 3. Results for the sensitivity analysis of average speed effect on emissions (pollutant variation compared to the base scenario).

Scenario	Pollutant	Higher Speed	Lower Speed
BAU	CO_2	−7.6%	+12.8%
	NO_x	−7.1%	+8.2%
AFR	CO_2	−7.6%	+12.7%
	NO_x	−7.8%	+7%
AEA	CO_2	−7.4%	+13%
	NO_x	−6.9%	+8.4%

Table 4. Results for the sensitivity analysis of average speed effect on emissions (scenario variation).

Pollutant		Base	Higher Speed	Lower Speed
CO_2	AFR vs. BAU	+10%	+10%	+9.9%
	AEA vs. BAU	−6.4%	−6.3%	−6.2%
NO_x	AFR vs. BAU	−10.9%	−11.5%	−11.9%
	AEA vs. BAU	−2.3%	−2.2%	−2.2%

6. Conclusions

The aim of this paper is to produce an assessment of the emissions generated by urban traffic in relation to the composition of the vehicle fleet. It provides a comparative framework for evaluating the effectiveness of different strategies directed at reducing urban traffic emissions. For the case study conducted using COPERT, Craiova, the biggest city in the Oltenia region and the sixth most populated city in Romania, was chosen. Each vehicle fleet category was disaggregated by fuel type and emission standard and annual mileage was allocated using an age-dependent activity algorithm to account for the decrease in distance traveled with vehicle age. The age of the current fleet is high, with the majority of passenger cars being older than 15 years, while in the case of light commercial vehicles, the situation is even worse (more than half are older than 20 years). Furthermore, the share of electrified vehicles in the fleet is very low. The baseline (2026) level of emissions was calculated and three short-term future scenarios (2030) were also created. The objective is to understand the impact of different pollution mitigation and TTW decarbonization strategies on the urban traffic emissions, which can help inform future policies in this area, rather than providing a highly accurate estimate of the city's emissions levels or proposing a specific strategy that could be promptly promoted. The three short-term future scenarios are BAU2030—Business As Usual (which follows the current trend of market evolution and assumes a certain level of replacement of the old vehicles with newer ones); AFR2030—Accelerated Fleet Renewal (which is defined by a more aggressive replacement rate of the older vehicles); and AEA2030—Accelerated Electromobility Adoption (which assumes an increased market share of electric vehicles among new vehicles). The improvements and differences observed between the scenarios might not be particularly pronounced over the short time horizon considered. Nevertheless, they are representative and scalable for longer-term strategic implementation. The limitations of the study are related to the lack of complete, publicly available, city-specific data required as model inputs and the average-speed-based emission calculation used in COPERT, which fails to capture some of the effects of traffic dynamics. Still, COPERT is a well-known tool in the scientific community and the EU-standard vehicle emission calculator and has proven very useful in spatial and temporal macroscopic analyses such as the one developed in this paper. In the future, the presented work can be extended to a larger study area, including non-urban vehicle activity and can be used to assess how changes in driving behavior are reflected in the final results.

As the most prevalent vehicle categories in the fleet, the petrol and diesel passenger cars are the main contributors to CO_2 emissions with over 150,000 tonnes from the almost 161,000 tonnes associated with all passenger cars, followed by the light commercial vehicles with 31,600 tonnes, while the bus fleet (which has undergone a renewal process in recent years) is responsible for just 3240 tonnes. The BAU2030 scenario projects minor reductions in CO_2 emissions for the passenger car and light commercial vehicle fleets due to the small increase in the share of electrified vehicles, especially hybrid passenger cars. The AEA2030 scenario achieves a reduction in passenger car CO_2 emissions of approximately 7% compared to BAU2030 (directly related to the projected 7% share of electric vehicles), while the slight increase in the AFR2030 scenario is attributable to the limitations of the COPERT methodology.

Diesel vehicles are by far the largest contributors to NO_x emissions, accounting for 90% of the total emissions. The fact that diesel light commercial vehicles are responsible for 29% of the total NO_x emissions although they represent just under 11% of the fleet can be explained by the advanced age of the diesel-dominated light commercial vehicle fleet. NO_x emissions in the BAU2030 scenario decrease considerably, by 33% for the passenger cars due to the replacement of some of the older diesel vehicles with newer technologies, while

the reduction is less significant in the case of light commercial vehicles. AFR2030 achieves the greatest reduction (10.7% compared to BAU2030 and 8.5% compared to AEA2030) because of the strategy of replacing older vehicles (the highest emitters).

More than 80% of total CO emissions are generated by the gasoline vehicles, with 71% being associated with the passenger cars and 11% with the light commercial vehicles, and vehicles with emission standards earlier than Euro 4 accounting for almost half of these emissions, despite being significantly less represented in the fleet. The phasing-out of the vehicles belonging to the oldest Euro standards leads to a considerable reduction in all 3 projected scenarios. The best result is obtained in the AFR2030 scenario due to the more intensive removal of the older vehicles from the fleet and their replacement with newer ones.

The $PM_{2.5}$ emissions are mostly associated with diesel passenger cars (60%), followed by diesel light commercial vehicles and gasoline passenger cars. $PM_{2.5}$ emissions produced by the diesel vehicles decrease by more than a third in all projected scenarios, with AFR2030 presenting slightly better results overall. The gasoline vehicles are responsible for most of the NMVOC emissions, with cold-start emissions predominating for the passenger cars and hot emissions dominant for light commercial vehicles. Emissions from gasoline vehicles are reduced by more than 50% in BAU2030 compared to the baseline scenario (due to the assumptions regarding fleet evolution), while the reductions achieved in the AFR2030 and AEA2030 scenarios compared to BAU2030 are rather limited, as the differences between the COPERT NMVOC emission factors for different Euro standards are considerably smaller than those between non-Euro and Euro-standard vehicles.

All three projected 2030 scenarios show significant emission reductions for the assessed pollutants compared to the baseline scenario (with the exception of CO_2 emissions in the AFR2030 scenario), mainly due to assumptions regarding the decrease in the number of older vehicles, which contribute disproportionately to the total emissions. Among these three scenarios, the best results are associated with the AFR2030 strategy because of the higher rate of fleet renewal, while the AEA2030 strategy offers improvements over BAU2030, but does not address the contribution of older vehicles. Regarding the CO_2 emissions, the AEA2030 strategy achieves the best results thanks to the higher share of electric vehicles in the fleet, while the AFR2030 strategy shows no clear advantage over the BAU2030 for reasons already explained. Therefore, the most suitable strategy appears to depend on the desired outcome and a combination of accelerated fleet renewal and higher electric vehicle adoption seems to be a logical approach to addressing both pollution mitigation and reduction in tailpipe CO_2 emissions, rather than enforcing policies to ban certain technologies that have recently seen significant improvements in reducing harmful emissions.

Author Contributions: Conceptualization, A.-C.O. and I.D.; methodology, I.D., D.T. and A.-C.O.; software, A.-C.O.; validation, D.T. and A.-C.O.; formal analysis, A.-C.O.; investigation, A.-C.O. and A.C.; data curation, A.-C.O. and A.C.; writing—original draft preparation, A.-C.O.; writing—review and editing, A.-C.O. and D.T.; visualization, A.-C.O. and A.C.; supervision, I.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data supporting this study are provided in the Appendix A, while the original data sources are cited in the References section.

Acknowledgments: During the preparation of this manuscript, the authors used GPT 5.6 Luna and Claude Sonnet 5.5 for the purposes of web research, data processing and manuscript verification. These platforms were used to identify publicly available data and extract relevant information from extensive datasets and were also helpful for consistency checks and verification of the manuscript for

errors, while improving the clarity of expression where necessary. The authors have reviewed and edited the output and take full responsibility for the content of this publication.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

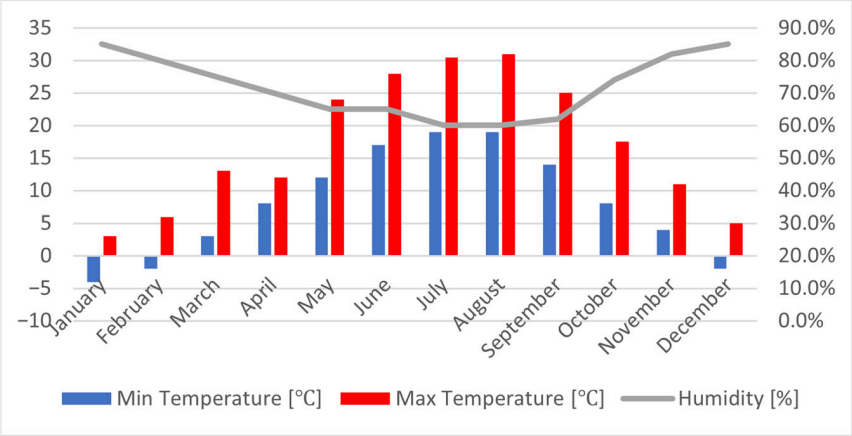


Figure A1. The environmental information specific to Craiova—the average monthly minimum/maximum temperature and humidity.

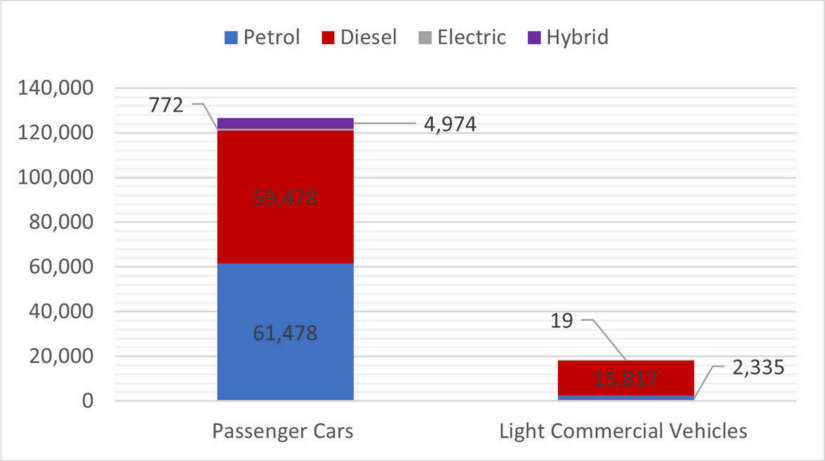


Figure A2. The distribution of fuel systems in passenger car and light commercial vehicle categories.

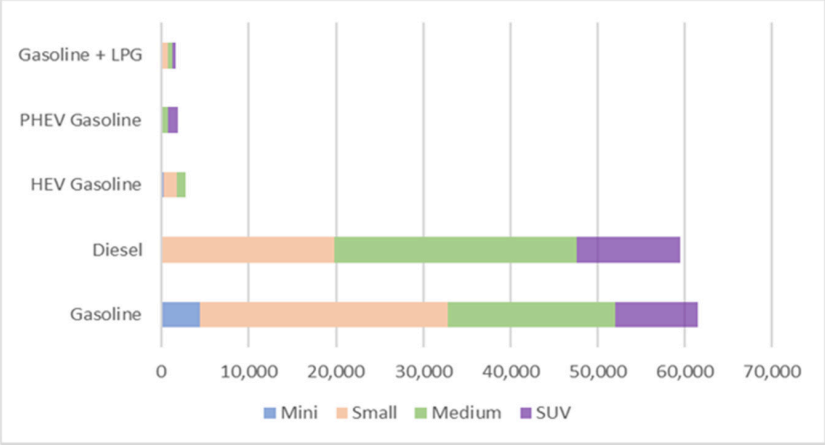


Figure A3. The most common classes in the passenger car category.

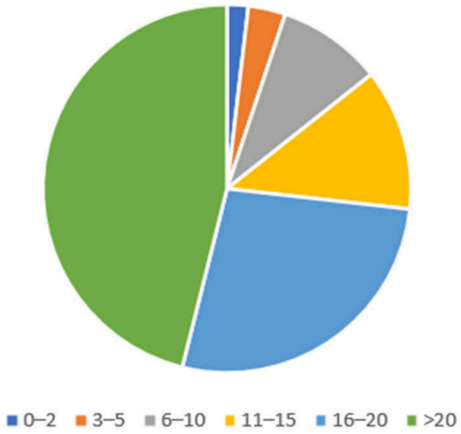


Figure A4. The age distribution of the Dolj passenger cars fleet (years).

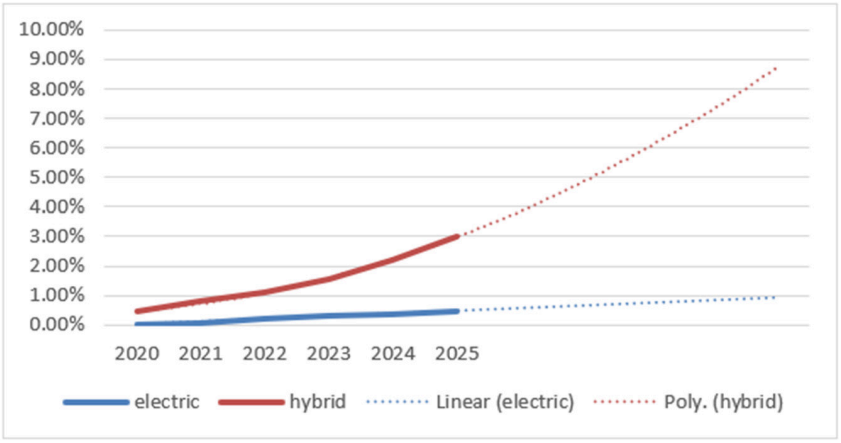


Figure A5. The projected share of electric and hybrid vehicles in the Dolj fleet.

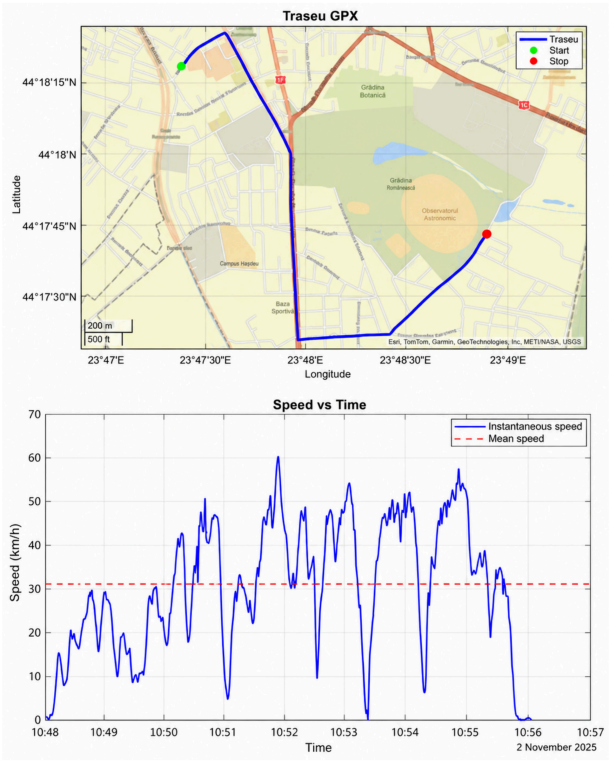


Figure A6. Example of measurements performed to determine traffic speed.

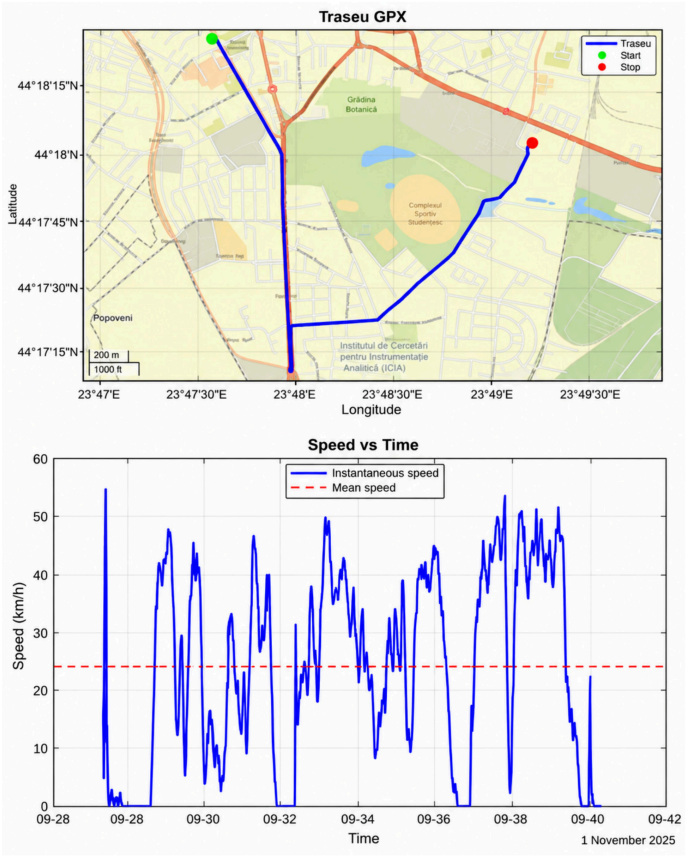


Figure A7. Example of measurements performed to determine traffic speed.

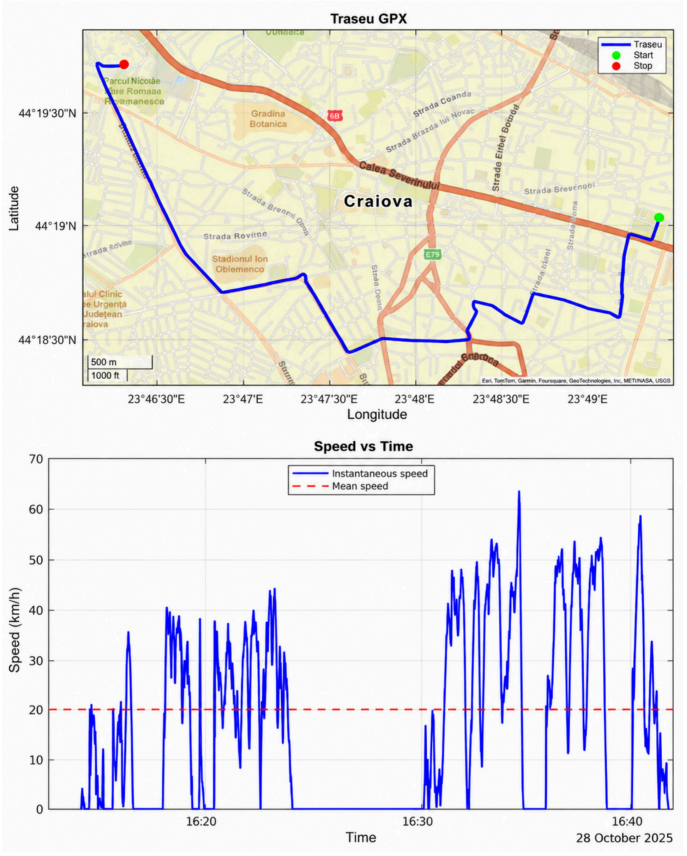


Figure A8. Example of measurements performed to determine traffic speed.

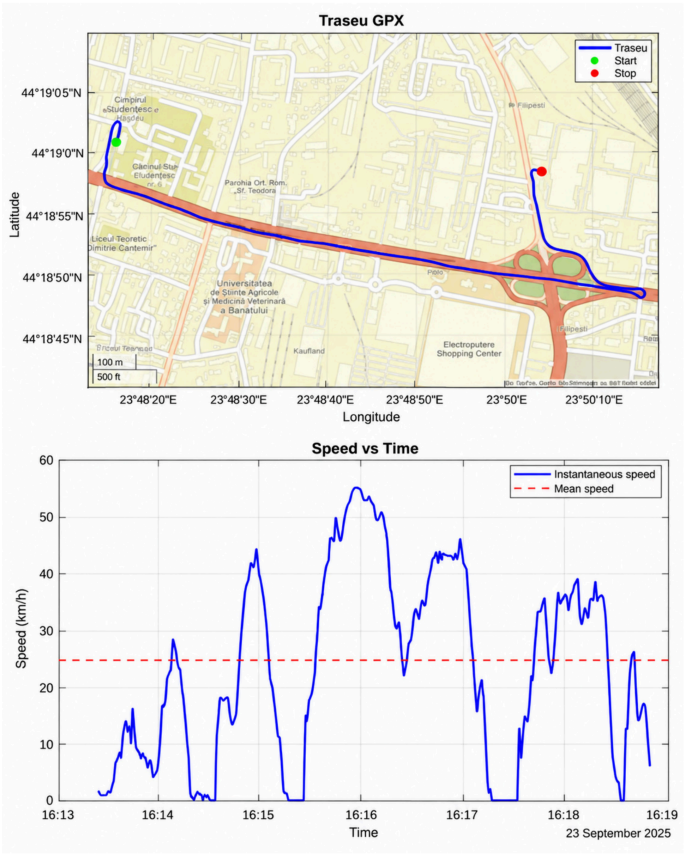


Figure A9. Example of measurements performed to determine traffic speed.

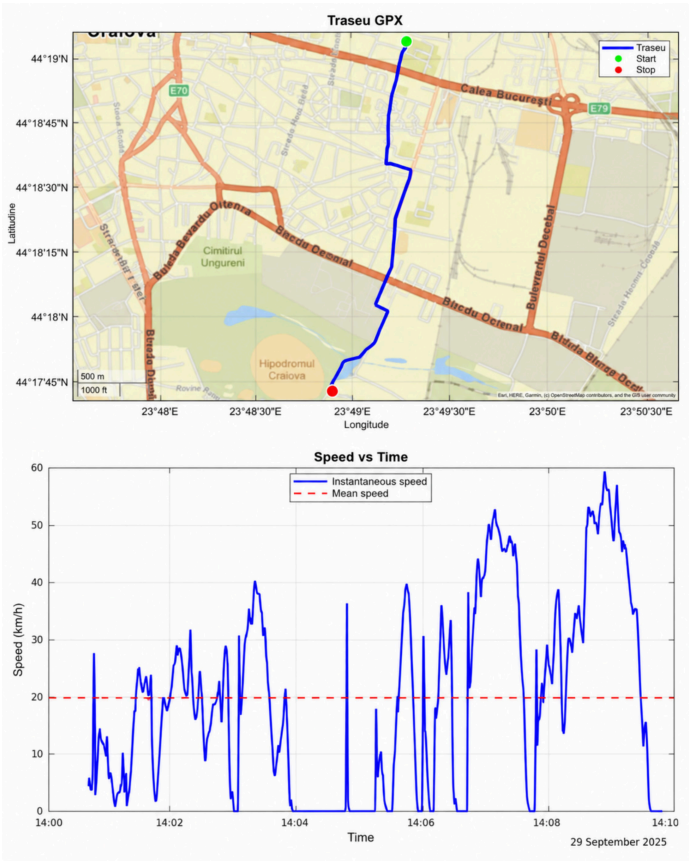


Figure A10. Example of measurements performed to determine traffic speed.

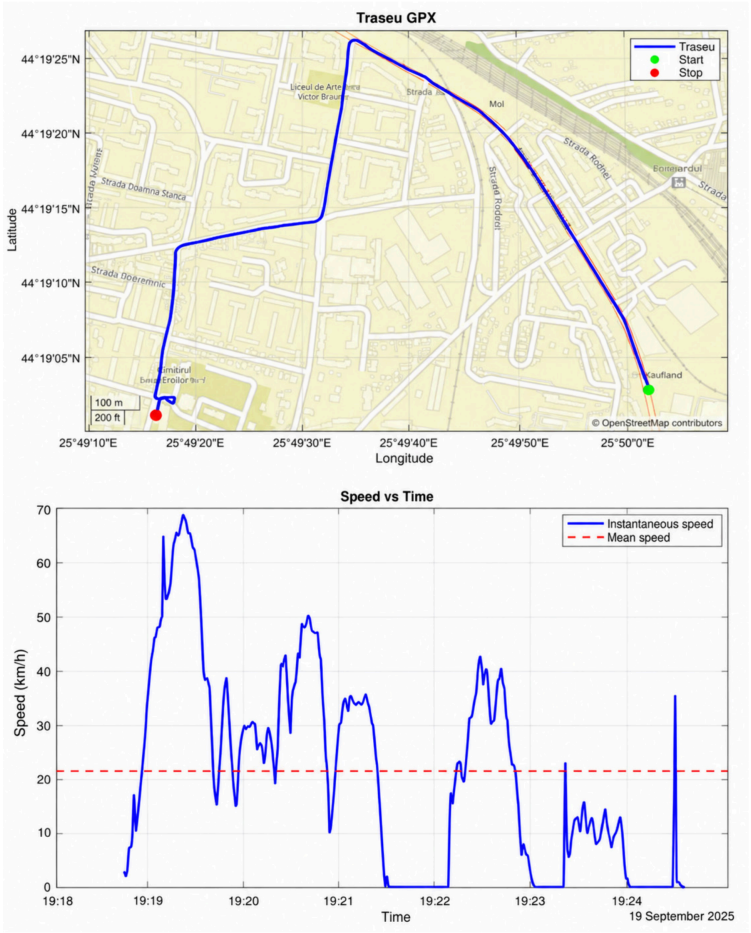


Figure A11. Example of measurements performed to determine traffic speed.

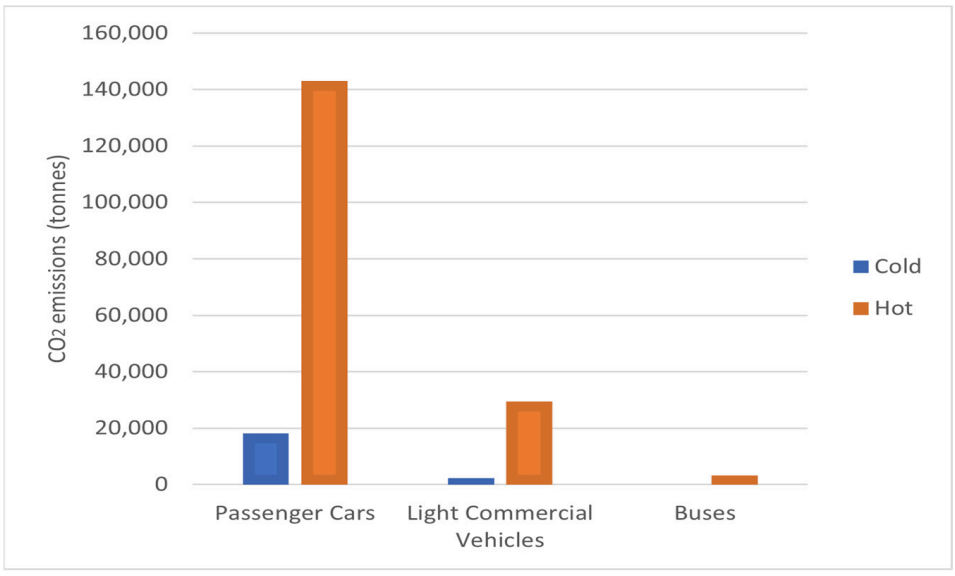


Figure A12. CO_2 total emissions (t) by vehicle category (Baseline2026 scenario).

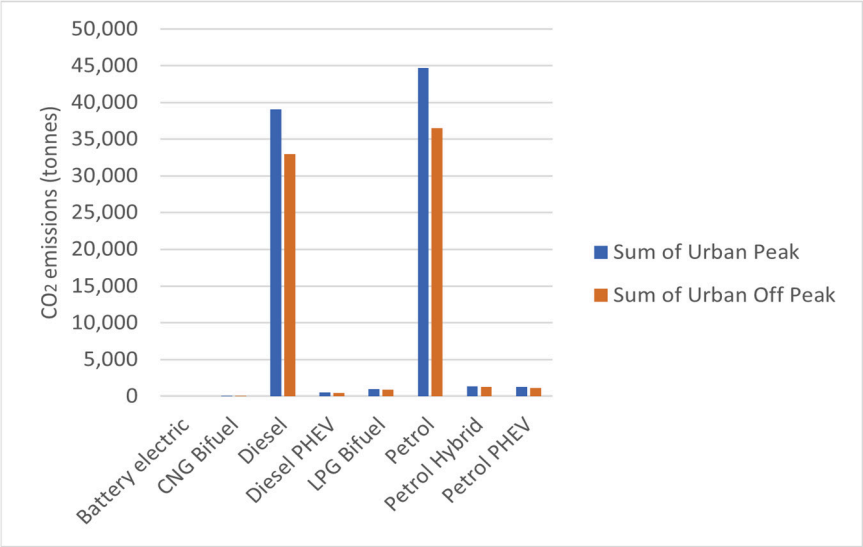


Figure A13. CO_2 passenger cars emissions (t) by fuel (Baseline2026 scenario).

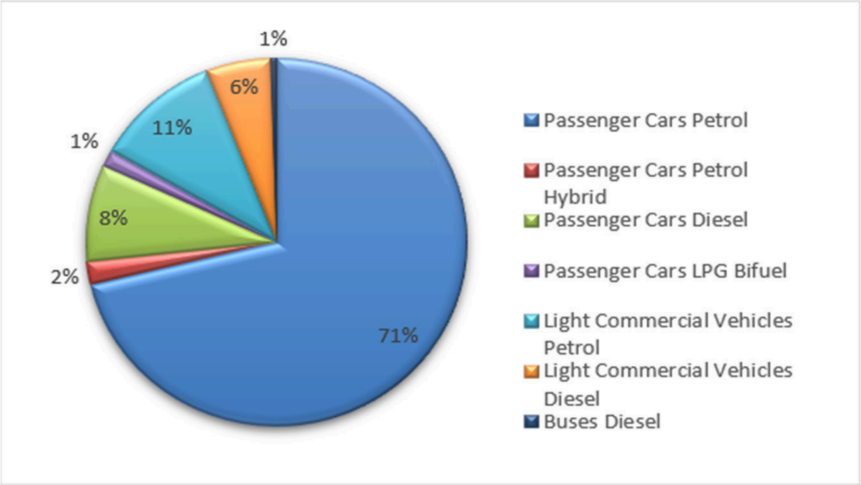


Figure A14. CO total emissions distribution by category and fuel (Baseline2026 scenario).

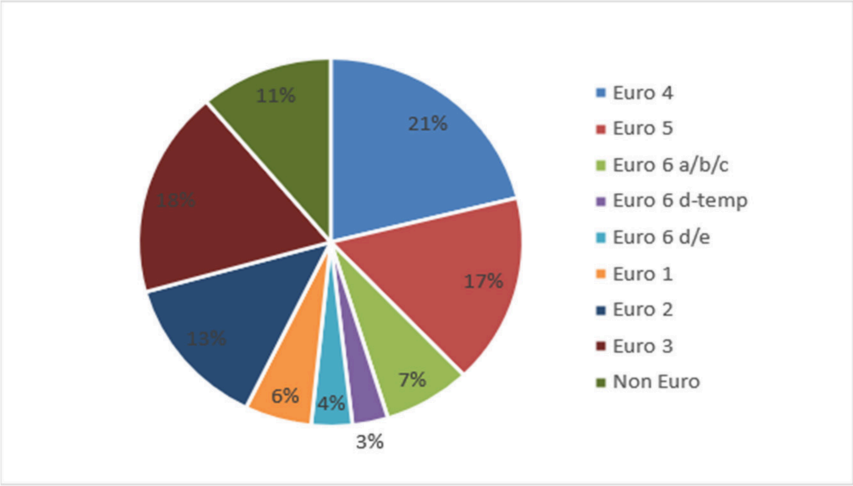


Figure A15. CO passenger cars emissions distribution by Euro standard (Baseline2026 scenario).

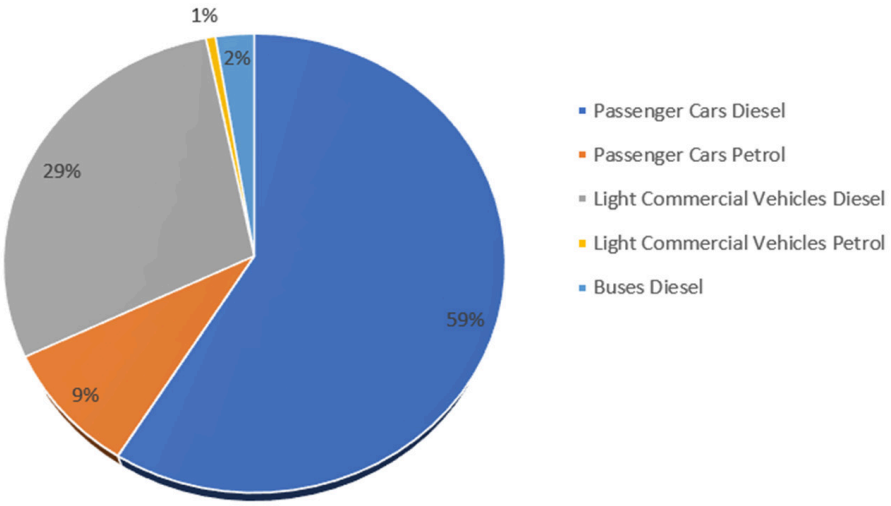


Figure A16. NO_x emissions distribution by vehicle category and fuel (Baseline2026 scenario).

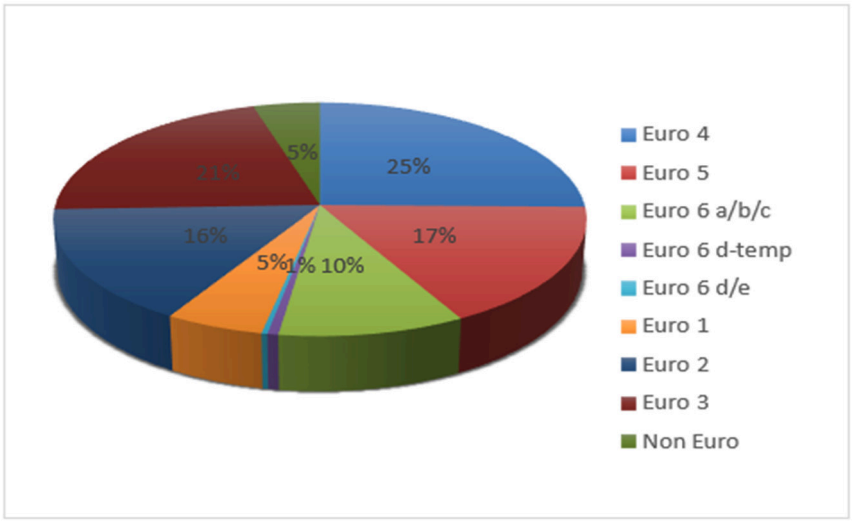


Figure A17. NO_x light commercial vehicles emissions distribution by Euro standard (Baseline2026 scenario).

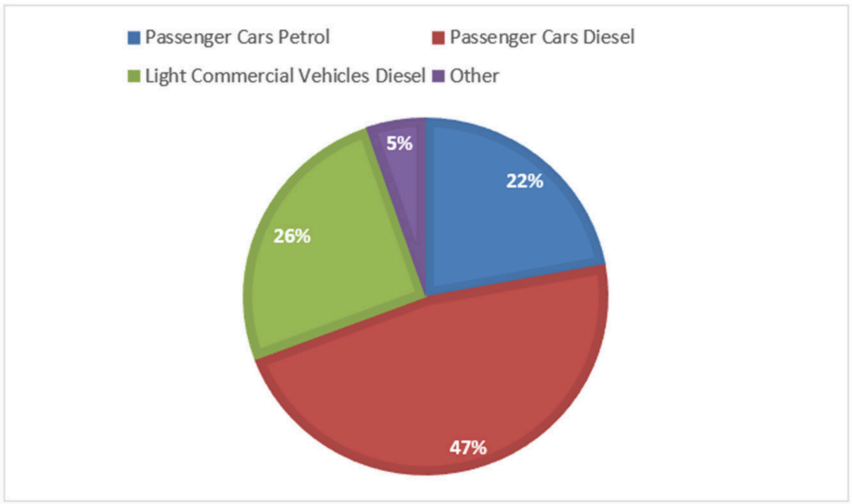


Figure A18. $PM_{2.5}$ emissions distribution by category and fuel (Baseline2026 scenario).

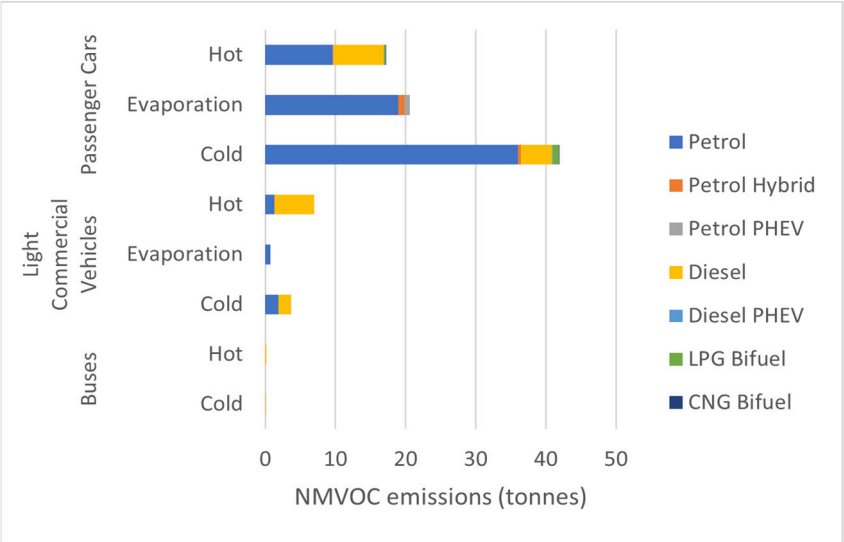


Figure A19. NMVOC emissions (t) by category and fuel (Baseline2026 scenario).

Table A1. Mini passenger cars fleet.

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	4372	-	173	-	-	40	-	28
Euro 6d/e	396	-	36	-	-	4	-	8
Euro 6d-temp	298	-	30	-	-	2	-	5
Euro 6 a/b/c	652	-	75	-	-	7	-	15
Euro 5	1012	-	24	-	-	11	-	-
Euro 4	2014	-	8	-	-	16	-	-

Table A2. Small passenger cars fleet.

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	28,411	19,862	1597	47	-	634	18	237
Euro 6d/e	1557	1090	322	14	-	41	1	71
Euro 6d-temp	1386	955	293	9	-	24	1	40
Euro 6 a/b/c	3295	2305	694	24	-	73	2	126
Euro 5	5005	3502	218	-	-	112	3	-
Euro 4	7597	5315	70	-	-	170	5	-
Euro 3	3829	2678	-	-	-	86	2	-
Euro 2	3350	2343	-	-	-	74	2	-
Euro 1	1436	1004	-	-	-	32	1	-
Euro 0	958	670	-	-	-	22	1	-

Table A3. Medium passenger cars fleet.

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	19,286	27,688	986	658	-	603	17	397
Euro 6d/e	1018	1531	227	175	-	39	1	119
Euro 6d-temp	968	1320	153	131	-	23	1	67
Euro 6 a/b/c	2239	3215	429	352	-	70	2	211
Euro 5	3400	4881	135	-	-	106	3	-
Euro 4	5160	7408	42	-	-	161	4	-
Euro 3	2600	3734	-	-	-	82	2	-
Euro 2	2275	3266	-	-	-	71	2	-
Euro 1	975	1400	-	-	-	30	1	-
Euro 0	651	933	-	-	-	21	1	-

Table A4. Large/SUV passenger cars fleet.

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	9429	11,928	139	1122	717	263	7	204
Euro 6d/e	883	1050	26	305	190	22	1	61
Euro 6d-temp	834	861	17	229	144	12	1	35
Euro 6 a/b/c	1638	2067	71	588	383	40	1	108
Euro 5	2082	2682	20	-	-	62	1	-
Euro 4	2326	3113	5	-	-	75	2	-
Euro 3	1048	1353	-	-	-	37	1	-
Euro 2	506	625	-	-	-	9	-	-
Euro 1	90	127	-	-	-	3	-	-
Euro 0	22	50	-	-	-	2	-	-

Table A5. Light commercial vehicles fleet.

	Petrol			Diesel			Electric		
Type	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**
Total	701	934	700	4745	6327	4745	6	7	6
Euro 6d/e	13	16	12	86	115	86	1	1	1
Euro 6d-temp	8	10	8	53	71	53	1	1	1
Euro 6 a/b/c	56	76	57	378	474	378	4	5	4
Euro 5	72	95	71	485	787	485	-	-	-
Euro 4	163	217	163	1102	1459	1102	-	-	-
Euro 3	156	209	156	1057	1390	1057	-	-	-
Euro 2	137	182	137	925	1204	925	-	-	-
Euro 1	58	78	58	397	504	397	-	-	-
Euro 0	38	51	38	262	323	262	-	-	-

Table A6. Mini passenger cars fleet (BAU 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	4382	-	565	-	-	40	0	50
Euro 7	136		130			4		17
Euro 6d/e	544	-	146	-	-	4	-	10
Euro 6d-temp	418	-	107	-	-	3	-	8
Euro 6 a/b/c	717	-	151	-	-	7	-	15
Euro 5	1006	-	24	-	-	10	-	-
Euro 4	1561	-	8	-	-	12	-	-

Table A7. Small passenger cars fleet (BAU 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	26,500	18,539	4809	142	-	592	17	410
Euro 7	2180	1625	1159	37	-	58	2	113
Euro 6d/e	3343	2339	1171	40	-	100	4	100
Euro 6d-temp	3212	2147	971	27	-	55	2	71
Euro 6 a/b/c	4442	3107	1267	38	-	82	3	126
Euro 5	5005	3502	197	-	-	112	3	-
Euro 4	5064	3543	44	-	-	113	3	-
Euro 3	1914	1339	-	-	-	43	-	-
Euro 2	1340	937	-	-	-	30	-	-

Table A8. Medium passenger cars fleet (BAU 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	18,037	25,895	2969	1981	-	564	16	548
Euro 7	1610	2481	713	478	-	57	2	148
Euro 6d/e	2296	3132	717	510	-	75	3	119
Euro 6d-temp	2170	2948	660	430	-	59	2	70
Euro 6 a/b/c	2911	4340	716	563	-	90	3	211
Euro 5	3400	4881	135	-	-	106	3	-
Euro 4	3440	4939	28	-	-	107	3	-
Euro 3	1300	1867	-	-	-	41	-	-
Euro 2	910	1307	-	-	-	28	-	-

Table A9. Large/SUV passenger cars fleet (BAU 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	8556	10,824	449	3543	2316	238	7	305
Euro 7	449	691	118	938	639	26	1	101
Euro 6d/e	1018	1235	119	948	644	37	1	61
Euro 6d-temp	826	975	70	760	450	23	1	35
Euro 6 a/b/c	1797	2274	103	897	583	37	1	108
Euro 5	2120	2682	34	-	-	54	1	-
Euro 4	1613	2041	5	-	-	43	2	-
Euro 3	535	677	-	-	-	16	-	-
Euro 2	198	250	-	-	-	3	-	-

Table A10. Light commercial vehicles fleet (BAU 2030).

	Petrol			Diesel			Electric		
Type	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**
Total	714	948	711	4820	6502	4819	15	16	15
Euro 7	15	22	15	108	147	106	3	3	3
Euro 6d/e	39	47	36	255	341	255	3	3	3
Euro 6d-temp	23	29	23	152	205	153	3	3	3
Euro 6 a/b/c	82	112	84	556	697	556	6	7	6
Euro 5	89	117	88	599	972	599	0	0	0
Euro 4	166	222	166	1125	1490	1125	0	0	0
Euro 3	159	213	159	1079	1420	1079	0	0	0
Euro 2	140	186	140	945	1230	945	0	0	0

Table A11. Mini passenger cars fleet (AFR 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	4382	0	565	0	0	40	0	50
Euro 7	387		141			5		17
Euro 6d/e	678	-	136	-	-	6	-	10
Euro 6d-temp	557	-	108	-	-	4	-	8
Euro 6 a/b/c	747	-	152	-	-	7	-	15
Euro 5	1006	-	24	-	-	10	-	-
Euro 4	1007		4			8	-	-

Table A12. Small passenger cars fleet (AFR 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	26,500	18,539	4809	142	-	592	17	410
Euro 7	4238	2965	1218	36	-	104	3	113
Euro 6d/e	4603	3220	1221	39	-	113	4	100
Euro 6d-temp	3999	2798	1051	27	-	80	2	71
Euro 6 a/b/c	4856	3397	1087	40	-	98	3	126
Euro 5	5005	3502	197	-	-	112	3	-
Euro 4	3798	2657	35			85	2	-

Table A13. Medium passenger cars fleet (AFR 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	18,037	25,895	2969	1981	-	564	16	548
Euro 7	3046	4373	724	468	-	99	3	152
Euro 6d/e	3132	4497	732	490	-	98	3	132
Euro 6d-temp	2806	4029	640	460	-	80	2	91
Euro 6 a/b/c	3072	4410	717	563	-	100	3	173
Euro 5	3400	4881	135	-	-	106	3	-
Euro 4	2580	3704	21	-	-	81	2	-

Table A14. Large/SUV passenger cars fleet (AFR 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	8556	10,824	449	3543	2316	238	7	305
Euro 7	1056	1378	119	898	589	41	1	101
Euro 6d/e	1388	1636	120	908	594	41	1	65
Euro 6d-temp	969	1295	70	830	550	30	1	41
Euro 6 a/b/c	1866	2276	103	907	583	40	1	98
Euro 5	2118	2682	34	-	-	54	1	-
Euro 4	1159	1557	3	-	-	32	1	-

Table A15. Light commercial vehicles fleet (AFR 2030).

	Petrol			Diesel			Electric		
Type	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**
Total	714	948	711	4820	6501	4820	15	16	15
Euro 7	95	126	94	653	899	653	3	3	3
Euro 6d/e	99	130	98	703	966	703	3	3	3
Euro 6d-temp	75	100	75	505	690	505	3	3	3
Euro 6 a/b/c	115	150	114	706	951	706	6	7	6
Euro 5	98	131	98	599	799	599	0	0	0
Euro 4	154	206	154	1125	1501	1125	0	0	0
Euro 3	78	105	78	529	695	529	0	0	0

Table A16. Mini passenger cars fleet (AEA 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	4155	0	565	0	0	34	0	283
Euro 7	95		130			2		90
Euro 6d/e	435	-	146	-	-	3	-	90
Euro 6d-temp	376	-	107	-	-	2	-	51
Euro 6 a/b/c	681	-	151	-	-	5	-	53
Euro 5	1006	-	24	-	-	10	-	-
Euro 4	1561	-	8	-	-	12	-	-

Table A17. Small passenger cars fleet (AEA 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	24,634	17,214	4809	142	-	515	12	3683
Euro 7	1526	1138	1159	37	-	35	1	1279
Euro 6d/e	2674	1871	1171	40	-	67	2	1271
Euro 6d-temp	2891	1932	971	27	-	44	1	619
Euro 6 a/b/c	4220	2952	1267	38	-	72	2	514
Euro 5	5005	3502	197	-	-	112	3	-
Euro 4	5064	3543	44	-	-	113	3	-
Euro 3	1914	1339	-	-	-	43	-	-
Euro 2	1340	937	-	-	-	30	-	-

Table A18. Medium passenger cars fleet (AEA 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	16,732	24,012	2969	1981	-	527	12	3776
Euro 7	1127	1737	713	478	-	45	1	1388
Euro 6d/e	1837	2506	717	510	-	68	2	1213
Euro 6d-temp	1953	2653	660	430	-	51	1	591
Euro 6 a/b/c	2765	4123	716	563	-	80	2	584
Euro 5	3400	4881	135	-	-	106	3	-
Euro 4	3440	4939	28	-	-	107	3	-
Euro 3	1300	1867	-	-	-	41	-	-
Euro 2	910	1307	-	-	-	28	-	-

Table A19. Large/SUV passenger cars fleet (AEA 2030).

	Petrol	Diesel	HEV Petrol	PHEV Petrol	PHEV Diesel	Petrol + LPG	Petrol + CNG	Electric
Total	8232	10,159	449	3543	2316	199	7	1521
Euro 7	324	484	118	938	639	12	1	497
Euro 6d/e	824	988	119	948	644	23	1	486
Euro 6d-temp	865	878	70	760	450	17	1	221
Euro 6 a/b/c	1715	2160	103	897	583	32	1	317
Euro 5	2140	2682	34	-	-	54	1	-
Euro 4	1623	2041	5	-	-	43	2	-
Euro 3	540	677	-	-	-	16	-	-
Euro 2	201	250	-	-	-	3		-

Table A20. Light commercial vehicles fleet (AEA 2030).

	Petrol			Diesel			Electric		
Type	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**	**N1-I**	**N1-II**	**N1-III**
Total	695	924	693	4693	6334	4693	176	176	176
Euro 7	11	15	11	76	103	74	44	44	44
Euro 6d/e	31	38	29	204	273	204	68	68	68
Euro 6d-temp	21	26	21	137	185	138	22	22	22
Euro 6 a/b/c	78	106	80	528	662	528	41	41	41
Euro 5	89	117	88	599	972	599	0	0	0
Euro 4	166	222	166	1125	1490	1125	0	0	0
Euro 3	159	213	159	1079	1420	1079	0	0	0
Euro 2	140	186	140	945	1230	945	0	0	0

References

1. Ntziachristos, L.; Gkatzoflias, D.; Kouridis, C.; Samaras, Z. COPERT: A European road transport emission inventory model. In *Information Technologies in Environmental Engineering: Proceedings of the 4th International ICSC Symposium, Thessaloniki, Greece, 28–29 May 2009*; Springer: Berlin/Heidelberg, Germany, 2009; pp. 491–504. [CrossRef]

2. Jaworski, A.; Mądziel, M.; Kuszewski, H. Sustainable public transport strategies—Decomposition of the bus fleet and its influence on the decrease in greenhouse gas emissions. *Energies* **2022**, *15*, 2238. [CrossRef]
3. Lejri, D.; Can, A.; Schiper, N.; Leclercq, L. Accounting for traffic speed dynamics when calculating COPERT and PHEM pollutant emissions at the urban scale. *Transp. Res. Part D Transp. Environ.* **2018**, *63*, 588–603. [CrossRef]
4. Obaid, M.; Torok, A.; Ortega, J. A comprehensive emissions model combining autonomous vehicles with park and ride and electric vehicle transportation policies. *Sustainability* **2021**, *13*, 4653. [CrossRef]
5. Macioszek, E.; Kurek, A. Road traffic distribution on public holidays and workdays on selected road transport network elements. *Transp. Probl.* **2021**, *16*, 127–138. [CrossRef]
6. Batterman, S. Temporal and spatial variation in allocating annual traffic activity across an urban region and implications for air quality assessments. *Transp. Res. Part D Transp. Environ.* **2015**, *41*, 401–415. [CrossRef] [PubMed]
7. EMEP/EEA. 2024. Available online: https://copert.emisia.com/wp-content/uploads/2024/07/1.A.3.b.i-iv-Road-transport-2024.pdf (accessed on 30 June 2026).
8. André, M.; Rapone, M. Analysis and modelling of the pollutant emissions from European cars regarding the driving characteristics and test cycles. *Atmos. Environ.* **2009**, *43*, 986–995. [CrossRef]
9. Heni, L.; Haj-Salem, H.; Lebacque, J.P.; Slimi, K. Integration and comparative analysis of COPERT and HBEFA emission models coupled with the BIDIM-GSOM traffic model for large-scale networks. *Transp. Res. Procedia* **2025**, *86*, 361–370. [CrossRef]
10. Smit, R.; Kingston, P.; Wainwright, D.H.; Tooker, R. A tunnel study to validate motor vehicle emission prediction software in Australia. *Atmos. Environ.* **2017**, *151*, 188–199. [CrossRef]
11. Li, F.; Zhuang, J.; Cheng, X.; Li, M.; Wang, J.; Yan, Z. Investigation and prediction of heavy-duty diesel passenger bus emissions in Hainan using a COPERT model. *Atmosphere* **2019**, *10*, 106. [CrossRef]
12. Quaassdorff, C.; Borge, R.; Pérez, J.; Lumbreras, J.; de la Paz, D.; de Andrés, J.M. Microscale traffic simulation and emission estimation in a heavily trafficked roundabout in Madrid (Spain). *Sci. Total Environ.* **2016**, *566–567*, 416–427. [CrossRef] [PubMed]
13. Al-lami, A.; Török, A.; Alatawneh, A.; Alrubaye, M. Future energy consumption and economic implications of transport policies: A scenario-based analysis for 2030 and 2050. *Energies* **2025**, *18*, 3012. [CrossRef]
14. Perez Rodríguez, J.; Castellanos Díez, H. Effect of local measures on the update of the circulating vehicle fleet and the reduction of associated emissions: 10 years of experience in the city of Madrid. *Cities* **2024**, *152*, 105214. [CrossRef]
15. Alam, M.S.; Hyde, B.; Duffy, P.; McNabola, A. Assessment of pathways to reduce CO_2 emissions from passenger car fleets: Case study in Ireland. *Appl. Energy* **2017**, *189*, 283–300. [CrossRef]
16. Lozhkina, O.; Lozhkin, V.; Ntziachristos, L. Estimation and prediction of the effect of alternative engine technologies and policy measures on the air quality in St. Petersburg in 2010–2030. *Archit. Eng.* **2018**, *3*, 31–35. [CrossRef]
17. Macedo, E.; Tomás, R.; Fernandes, P.; Coelho, M.C.; Bandeira, J.M. Quantifying road traffic emissions embedded in a multi-objective traffic assignment model. *Transp. Res. Procedia* **2020**, *47*, 648–655. [CrossRef]
18. Kinsella, L.; Stefaniec, A.; Foley, A.; Caulfield, B. Pathways to decarbonising the transport sector: The impacts of electrifying taxi fleets. *Renew. Sustain. Energy Rev.* **2023**, *174*, 113160. [CrossRef]
19. Trofimenko, Y.; Komkov, V.; Trofimenko, K. Forecast of energy consumption and greenhouse gas emissions by road transport in Russia up to 2050. *Transp. Res. Procedia* **2020**, *50*, 698–707. [CrossRef]
20. Borge, R.; De Miguel, I.; de la Paz, D.; Lumbreras, J.; Pérez, J.; Rodríguez, E. Comparison of road traffic emission models in Madrid (Spain). *Atmos. Environ.* **2012**, *62*, 461–471. [CrossRef]
21. Primăria Municipiului Craiova. Studiu Privind Fluxul de Călători în Municipiul Craiova. Available online: https://www.primariacraiova.ro/ro/a/134/studiu-privind-fluxul-de-calatori-%C3%AEn-municipiul-craiova (accessed on 5 July 2026).
22. Climate-Data.org. Craiova Climate Data. Available online: https://ro.climate-data.org/europa/romania/dolj/craiova/ (accessed on 1 July 2026).
23. Primăria Municipiului Craiova. Plan de Mobilitate Urbană Durabilă Pentru Polul de Creștere Craiova. Available online: https://www.primariacraiova.ro/ro/a/2591/consultare-public%C4%83-a-documentului-%E2%80%9Eplanul-de-mobilitate-urban%C4%83-durabil%C4%83-pentru-zona-metropolitan%C4%83-craiova (accessed on 5 July 2026).
24. Direcția Generală Permise de Conducere și Înmatriculări. Available online: https://dgpci.mai.gov.ro/ (accessed on 10 July 2026).
25. Guvernul României. Parc auto România. Data.gov.ro. Available online: https://data.gov.ro/dataset/parc-auto-romania (accessed on 12 July 2026).
26. Caserini, S.; Pastorello, C.; Gaifami, P.; Ntziachristos, L. Impact of the dropping activity with vehicle age on air pollutant emissions. *Atmos. Pollut. Res.* **2013**, *4*, 282–289. [CrossRef]
27. Lebeau, P.; Macharis, C.; Van Mierlo, J.; Lebeau, K. Electrifying light commercial vehicles for city logistics? A total cost of ownership analysis. *Eur. J. Transp. Infrastruct. Res.* **2015**, *15*, 551–569. [CrossRef]

28. Rout, C.J. An Environmental and Economic Assessment of Introducing Hydrogen to a Combined Heavy Duty/Off-Road Vehicle Fleet in the UK. Integrated PhD and Master Thesis, University of Leeds, England, UK, 2023. Available online: https://etheses.whiterose.ac.uk/id/eprint/33122/ (accessed on 13 July 2026).
29. Statistici Auto. Trends. Available online: https://statisticiauto.ro/#trends (accessed on 15 July 2026).
30. Banca Transilvania. Înmatriculările în România. Available online: https://blog.bancatransilvania.ro/en/the-macro-zone/inmatricularile-in-romania (accessed on 15 July 2026).
31. Möring-Martínez, G.; Senzeybek, M.; Hasselwander, S.; Schmid, S. Quantifying the impact of fleet turnover on electric vehicle uptake in Europe. *Transp. Res. Part D Transp. Environ.* **2025**, *147*, 104945. [CrossRef]
32. Pérez, J.; de Andrés, J.M.; Borge, R.; de la Paz, D.; Lumbreras, J.; Rodríguez, E. Vehicle fleet characterization study in the city of Madrid and its application as a support tool in urban transport and air quality policy development. *Transp. Policy* **2019**, *74*, 114–126. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.