Article citation info:
Pryciński P. Selected emissivity assessment issues for electric and hybrid vehicles. Combustion Engines. 0000;XXX(X):xx-xx. https://doi.org/10.19206/CE-205274

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Combustion Engines
Polish Scientific Society of Combustion Engines

Selected emissivity assessment issues for electric and hybrid vehicles

ARTICLE INFO

Received: 11 April 2025
Revised: 12 May 2025
Accepted: 18 May 2025
Available online: 6 June 2025

This paper presents selected issues concerning the assessment of the emissivity of electric and hybrid vehicles, referred to as zero- or low-emission vehicles. This paper proposes an analytical method to determine air pollutant emissions generated by road electric vehicles and presents the results of air pollutant emissions measurements of hybrid vehicles obtained during real driving emissions tests (RDE). Air pollutant emissions measurements for hybrid vehicles were corrected for electricity consumption during operation and the pollutant emissions arising from electricity generation. The paper discusses the issue of air pollutant emissions of electric vehicles in relation to the changing sources of electricity generation in Poland over the past decade. It also presents the dynamics of change of in-use and newly registered electric and hybrid vehicles in Poland between 2022 and 2023. The aim of this paper is to compare the emissivity of electric vehicles, as well as hybrid vehicles, using the analytical method proposed in the paper to determine air pollutant emissions generated by electric vehicles.

Key words: *emissivity assessment, real driving emissions tests, electric, hybrid vehicles, exhaust emissions*

1. Introduction

Electricity production in Poland has been based on fossil fuels for many years. Air pollutant emissions accompanying this production change depend on the fuels used for electricity generation. Modern zero- or low-emission vehicles are equipped with electric motors. These are fully electric or hybrid vehicles. Their emissions, therefore depend on the sources used to generate electricity in Poland and worldwide. The main primary fossil fuels used in Poland for electricity production are hard coal, brown coal, natural gas, coalbed methane, and oils of all kinds. By classifying the above sources into two sets of conventional fuels, including hard coal, brown coal, natural gas, and RES fuels, including biomass, hydro, pumped-storage hydroelectricity, photovoltaics, and wind turbine plants, it is possible to track changes in the use of individual primary sources for electricity production in Poland. Poland has experienced significant developments in this regard over the last 10 years [26]. The substitution of primary materials for electricity production is shown in Fig. 1.

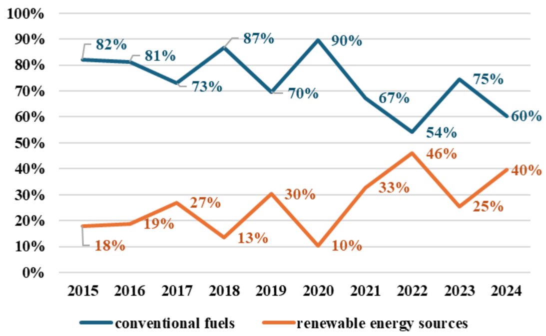

Fig. 1. Sources of electricity production in Poland 2015–2024 [26]

Noteworthy is the more than 20% decrease in the share of conventional fuels in electricity production in Poland [26] and the more than 22% increase in the share of renewable energy sources in electricity production. The decline in electricity produced from fossil fuels over the last decade has been dictated by the restructuring measures carried out in Poland in the area of the mining industry and the development of the renewable energy sector, particularly in wind, solar, and water production. The share of fossil fuels in electricity production in Poland is still high compared to the EU and to other countries in the EU [25]. When comparing Poland's results with those recorded in 2023 for other EU countries, it is noteworthy that only in Cyprus (79%) and Malta (87%) the share of electricity produced from fossil fuels is higher than in Poland. Higher shares of fossil fuels in electricity production in the EU are present in countries without deployed nuclear power. An example is Italy, where the share of electricity production from fossil sources was close to 55% in 2023. In terms of electricity production from conventional and renewable sources, Italian statistics are most similar to the Polish electricity production. Publicly available statistics [25] show a significant share of electricity produced from nuclear sources in the European Union. The share of nuclear power in the electricity production mix will reach more than 23% in 2023. The use of primary materials for electricity production in the EU is shown in Fig. 2.

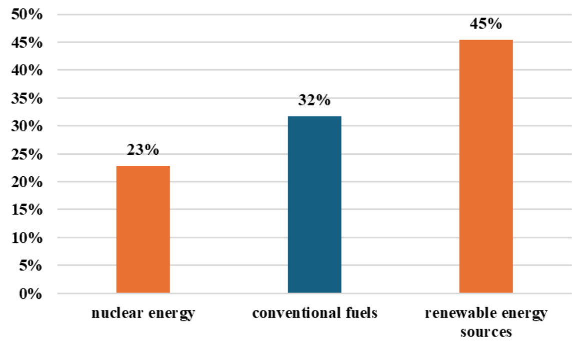

Fig. 2. Sources of electricity production in the European Union in 2023 [26]

The share of energy from renewable sources, on the other hand, was over 45%. Importantly, the share of electricity produced from renewables in the EU is close to the share of RES in Poland in 2024. Poland should achieve EU averages in the coming years, considering the growth dynamics of electricity production from RES.

Comparing the statistics of Poland and the EU, the share of renewable sources in electricity production in Poland nearly reached the EU average in 2024. The share of fossil fuels was unfortunately almost twice as high in Poland as in the EU. The reason for this may be the lack of nuclear power production and the ongoing restructuring processes in the mining industry. The functioning of the power system in Poland depends on regulatory changes and a number of legal conditions.

The Green Deal is the most important legal basis shaping the current and future industrial, transport and climate policy of Poland and Europe. At the European Union level, the technological trends associated with the electricity sector's decarbonisation, i.e., moving away from coal and reducing the role of natural gas, as well as the development of nuclear power, will play a fundamental role in the evolution of the power system and its surroundings in the near future. It is noteworthy that the development of renewable energy, energy storage, and the popularisation of zero-emission onsite transport means will continue to be supported. Moreover, a dynamic development of prosumer energy based mainly on photovoltaics is taking place in Poland. Solar-based energy, especially from 2020 onwards, has played a significant role in the national energy mix, as illustrated in Figure 1. There has been a marked development of large-scale photovoltaics, i.e., photovoltaic farms being established in larger suburban areas. Wind power plants are being built on land and in the Baltic Sea area [24]. Despite the high rate of change and new investments being undertaken, several key barriers to the wider development of renewable electricity production have been identified in Poland, which also has implications for electric vehicle emissions. One of the main barriers to the development of renewable energy is the issue of storing energy during periods of overproduction so that it can be used at times when generation from RES sources is not possible, i.e., during, for example, wind or sun shortages. The concept of energy storage is therefore being developed. Technological developments are favoured by falling component costs and the growth of commercial energy storage facilities for power system needs. However, regulatory support for the development of storage technologies is much less extensive than support for production technologies, and the rate of investment in new storage facilities is lower than for production technologies, which significantly limits the further integration of RES technologies into power systems. Another barrier related to transport is the rather slow pace of electromobility development. The widely heralded announcements of electromobility development are only partially reflected in the number of newly registered electric vehicles.

Nevertheless, initiatives are being taken to launch financial support and subsidies for the purchase of electric vehicles in Poland, e.g., the OurEvehicle programme. Announced in 2025 by the National Fund for Environmental Protection and Water Management and the Ministry of Climate and the Environment, the programme envisages a maximum funding amount of PLN 40,000. Only new M1-category electric vehicles that have not previously been registered and whose price does not exceed the net amount of PLN 225,000 are eligible for support [30]. At the same time, the development of infrastructure to ensure the efficient use of electric vehicles has been relatively slow, diverging significantly from plans to electrify road transport. In this respect, it is worth pointing out that at the end of July 2024, there were just over 70,000 passenger and commercial all-electric vehicles registered in Poland [3]. Between the beginning of the year and July 2024, the number of vehicles increased by 6% year-on-year. At the end of July 2024, there were 7,563 publicly accessible electric vehicle charging points in Poland, including 4,163 stations. As the number of electric vehicles has grown, so has the charging infrastructure. But the pace of development was too slow due to the condition of the power grids, among others. In July 2024, 308 new electric vehicle charging points were launched. Despite an inauspicious start in 2024, the International Energy Agency predicts that electric vehicles worldwide will reach a 20% market share by the end of 2024 [3]. Another barrier to the development of renewable energy is the price war among RES technologies and the competition between European players and the Chinese market. The production of components used in RES technologies in China, i.e., photovoltaic panels, batteries, energy storage, and electric vehicles, takes place on a large scale, making it unprofitable to produce for markets outside China. Such action results in a significant drop in component prices and the unprofitability of their production in European conditions, for example. This has resulted in the deepening monopolisation of many sectors, including, more recently, the EU's increasing dependence on Chinese supplies. The marked growth of Chinese capital in Europe is also evident in the transport sector. More new models and brands of Chinese-made vehicles are coming on sale, including SANY electric trucks [31] used in Poland for long-distance freight transport or service provision in the construction industry, for example. The above barriers inhibit the achievement of the green transition's goals, i.e. the European Union's energy autonomy and the reduction of air pollutant emissions also in the transport sector within the next decade. The commissioning date of the first nuclear units in Poland is 2035; the middle of the next decade will be crucial for the decarbonisation of energy and transport in Poland [24]. The larger-scale deployment of electric and hybrid vehicles is part of activities aimed at sustainability. Issues related to the modelling of sustainable transport systems [5], the search for air pollution emission reduction solutions [1] and scenarios with the development of electromobility [6] and risk analyses for the development of low-carbon transport and supply markets are widely published in the literature [8–10, 17]. In addition to the promotion of low- and zero-emission vehicles, strategies are being formulated to reduce emissions in urban areas, solutions to improve the cost-effectiveness of electric vehicle operation [4, 11] and studies in the field of air pollutant emission measurements of conventional, hybrid, electric [12–14, 18, 20, 33] and hydrogen vehicles [19].

2. Methodology

The paper proposes an analytical method to determine the air pollutant emissions generated by electric vehicles and presents the results of road tests measuring a hybrid vehicle's air pollutant emissions. Air pollutant emissions from vehicle operation usually boil down to determining the amount of air pollutants generated by a mode of transport during operation and affecting the external environment. Depending on the source of the pollution generated in the vehicles, this could be pollution coming directly from fuel combustion or from other sources. With regard to the issue of air pollutant emissions, different methods of measuring them are often pointed out. Common methods include the following:

- well to tank (WTT), understood as a method of measuring the amount of air pollutant emissions generated in the initial activity chain, e.g., involving extraction and production of the fuel used in a particular type of transport mode
- tank to wheel (TTW), understood as a method of measuring air pollutant emissions resulting from the direct consumption of fuel by a mode of transport
- well to wheel (WTW), understood as a method of measuring emissions along the entire chain, starting from the very source of an energy raw material in question to its use, i.e. from the extraction of the original propellant, e.g. oil, to the production and consumption of the fuels in the vehicle.

Measurements of air pollutant emissions should be selected depending on the mode of transport and the type of propellant used to power the vehicles. With regard to electric vehicles, on-site air pollutant emissions resulting from fuel combustion do not occur, so the TTW emissions measurement method is not applicable in this case. However, it is possible to use the WTT method to determine air pollutant emissions from electricity generation to power electric vehicles. In order to measure air pollutant emissions occurring during the vehicle operation phase, the focus should be on WTT emissions (electric vehicles, hybrid vehicles) and TTW emissions (conventional and hybrid vehicles).

For electric vehicles, the main air pollutant emission arising from electricity generation are applicable. These emissions are monitored and published by the National Centre for Emissions Management [22].

Table 1. Emission factors in [kg/MWh] for electricity end-users [22]

Year of measurements	Air pollutant type			
	CO_2	SO_2	NO_x	CO
2014	823	1.571	1.049	0.233
2015	798	1.516	0.954	0.234
2016	781	0.818	0.824	0.252
2017	778	0.729	0.741	0.265
2018	765	0.681	0.631	0.275
2019	719	0.511	0.576	0.233
2020	698	0.509	0.522	0.203
2021	708	0.505	0.505	0.237
2022	685	0.436	0.436	0.261
2023	597	0.363	0.392	0.222

Over the last decade, there has been a marked change in the emission factors for the main air pollutants from electricity production in Poland. The main air pollutants from electricity production in Poland are carbon dioxide, sulphur dioxide, nitrogen oxides, particulate matter, and carbon monoxide. Based on the data presented in Table 1, it can be concluded that over the last decade, the rate of CO_2 emissions during electricity generation in Poland has decreased by nearly 27%. The largest reduction in air pollutant emissions from electricity production in Poland was recorded for sulphur oxides (nearly 77%). In contrast, nitrogen oxides emissions in electricity production in Poland have dropped by nearly 63% in the last decade. The smallest reduction in air pollutant emissions in electricity production in Poland was recorded for carbon monoxide (5%). The reductions in air pollutant emissions in electricity production in Poland are directly related to Poland's energy mix and its significant change in the period from 2014 to 2024. The energy changes introduced in Poland are directly and positively reflected in air pollutant emissions generated in electricity production. The milestone for reducing emissions during electricity production in Poland will be the commissioning of the first nuclear power plant.

The emissions of electric vehicles in terms of propellant consumption come down to the determination of emissions during the operation of the mode of transport, in terms of the electric motor's electricity consumption, usually expressed as part of a combined cycle in terms of the power consumed per kilometre (Wh/km). Within the framework of the analytical method proposed in this paper, air pollutant emissions of electric vehicles can be determined based on emissivity factors published periodically by the National Centre for Emissions Management [22]. Moreover, air pollutant emissions of electric vehicles can be determined based on current and historical data, thereby making it possible to monitor changes in electric vehicle emissions in terms of changes to Poland's energy mix, as provided historically in Table 1. Using the KOBIZE values, the calculation of air pollutant emissions based on the proposed analytical method for electric vehicles, taking into account the variability of emissions over time due to changes in Poland's energy mix, is based on the following equations in mass units of each type of air pollutant per kilometre travelled by a specific type of electric vehicle.

$$E_{CO2} = P_k \times W_{1,y} \tag{1}$$

$$E_{SO2} = P_k \times W_{2,y} \tag{2}$$

$$E_{NOx} = P_k \times W_{3,y} \tag{3}$$

$$E_{CO} = P_k \times W_{4,y} \tag{4}$$

$$E_{T,y} = E_{CO2} + E_{SO2} + E_{NOx} + E_{CO} \tag{5}$$

where the individual symbols stand for specific air pollutant emissions, i.e.: $W_{1,y}$ – CO_2 emissions taken from Table 1 for k-th vehicle type and y-th assessment year; $W_{2,y}$ – SO_2 emissions taken from Table 1 for k-th vehicle type and y-th assessment year; $W_{3,y}$ – NO_x emissions taken from Table 1 for k-th vehicle type and y-th assessment year; $W_{4,y}$ – CO emissions taken from Table 1 for k-th vehicle type and y-th assessment year; $E_{T,y}$ – total emissions of main pollutants (CO_2, SO_2, CO, NO_x) for the k-th vehicle type in the y-th assessment year; P_k – energy consumption by the k-th electric vehicle type [kWh/km].

Air pollutant emissions from the operation of hybrid road vehicles, on the other hand, depend on the type of hybrid vehicle. As part of the paper, the RDE road test methodology was used to determine the emissions of hybrid vehicles. Air pollutant emissions were measured with the SEMTECH DS analyser, held by the Poznan University of Technology. The research was carried out under a discipline grant by the author. Warsaw University of Technology funded the grant.

The type of hybrid vehicle depends primarily on the configuration of the vehicle's power unit. Hybrid vehicles use an internal combustion engine and an electric motor for propulsion. Typically, the electric motor of a hybrid vehicle assists the internal combustion engine. There are three main types of hybrid vehicles, i.e., so-called full hybrids (HEVs), mild hybrids (mHEVs), and plug-in hybrids (PHEVs).

Considering the environmental impact issues of hybrid vehicles, the air pollutant emissions of hybrid vehicles are determined during real driving emissions tests (RDE). In addition, in terms of plug-in vehicles and MHEVs, it is possible to correct roadside measurements of air pollutant emissions by the value of air pollutant emissions that occur in the production of electricity consumed by the hybrid vehicle in the course of carrying out transport tasks. Thus, the emission results from road testing can be corrected (augmented) by the results of emissions generated by powering engines using electricity, based on the analytical method indicated earlier. The use of hybrid technologies in road vehicles is very common. As shown in Fig. 3 and Fig. 4, the popularity of electric and hybrid vehicles is significant.

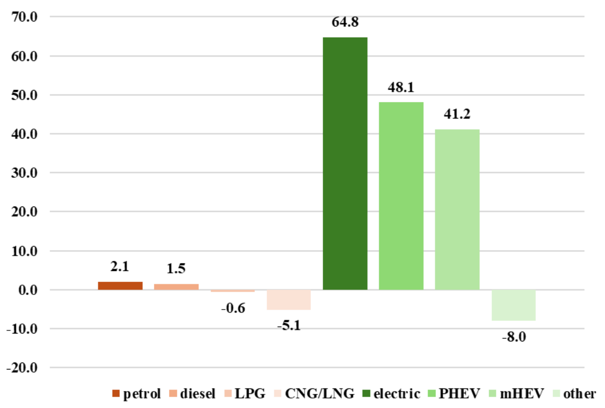

Fig. 3. Change in the number of registered vehicles in Poland, 2022/2023 [%] [23]

More than 48% more plug-in hybrid vehicles were registered in 2023 than in 2022. There was a similar increase in hybrid vehicle registrations in 2023 relative to 2022 for mHEVs (41%) [23]. The largest percentage increase in the number of vehicles registered year-on-year was for electric vehicles. Analysing new vehicle registrations, the highest increases of over 50% were also recorded for electric vehicles. Significantly, the year-on-year numbers of conventionally powered vehicles show little change, in favour of low- or zero-emission vehicles. Nevertheless, in absolute numbers, combustion vehicles are the largest group registered in Poland, which will not change in the coming years.

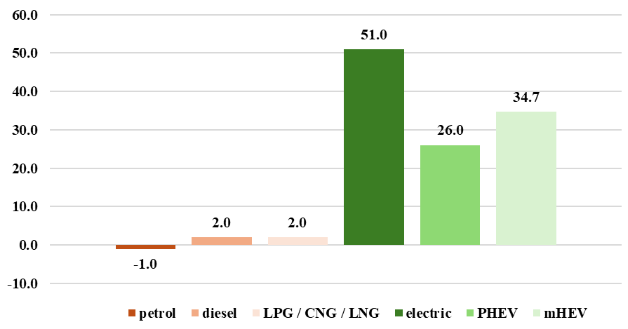

Fig. 4. Percentage change in the number of new registered vehicles in Poland 2022/2023 [23]

The measurement of air pollutant emissions of hybrid vehicles can be carried out in accordance with the real driving emissions (RDE). However, it should be mentioned that with the introduction of successive air pollutant emission standards, the methodologies for measuring air pollutant emissions have changed. Air pollutant emission measurements carried out under NEDC (New European Driving Cycle) or WLTP (Worldwide Harmonized Light-Duty Vehicles Test Procedure) laboratory conditions have been plagued by poor correlation between vehicle dynamic conditions on the dynamometer and in real traffic conditions. Manufacturers have often adapted combustion engines to meet all requirements only during laboratory tests. Hence, the measurement of exhaust gas emissions in real traffic conditions based on the RDE emission measurement test has been implemented [21]. Every car approved from 2017 onwards must meet RDE test requirements in addition to the WLTC test requirements. The compounds that appear in the exhaust gas when the vehicle is operated in urban, extra-urban, and motorway conditions are analysed during the road tests. The test route must be adjusted so that the test's continuity is not interrupted. Data should also be recorded without any interruption. The RDE test should be carried out on paved carriageways during working days. The regulations prohibit the excessive use of the neutral gear in the initial stage after starting the engine during the test. The route should run for a minimum of 16 km in urban, non-urban, and motorway conditions [14]. Hybrid vehicle tests were carried out in the Poznań agglomeration as part of this paper. Vehicle speeds in the urban area did not exceed 60 km/h, with average speeds between 15 and 45 km/h. The proportion of each section was approximately one-third of the length of the entire test route. Deviations of 10 percentage points were allowed, but the urban section should not represent less than 29% of the total test route. Moreover, stops, i.e., when the car is not moving faster than 1 km/h, should not account for more than 30% of the total route in the test's urban section. In the non-urban section, the vehicle travelled at least 16 km and travelled at speeds between 60 and 90 km/h. In the motorway section, the vehicle travelled at higher speeds, i.e., from 90 km/h, and the maximum speed did not exceed 145 km/h [14]. In terms of plug-in vehicles and MHEVs, the results of on-road air pollutant emissions tests can be further corrected, plus the value of air pollutant emissions that arise from the generation of electricity consumed by the vehicle in the course of its transport tasks.

3. Results

Given the analytical method described above for determining the air pollutant emissions generated by electric vehicles, as well as the air pollutant emissions published by KOBIZE [22], it is possible to determine TTW emissions for electric vehicles. The characteristics of the electric vehicles for which air pollutant emissions were determined are shown in Table 2.

Table 2. Characteristics of selected electric vehicles [28, 29, 32]

No.	Vehicle brand	Model	Energy consumption [Wh/km]	Maximum range [km]
1	Tesla	S Plaid	187	600
2	BMW	i5 eDrive40	159	582
3	Nissan	Leaf	166	285
4	VW	ID.3	152	388
5	Hyundai	IONIQ 6	139	429

Knowing the energy consumption during the electric vehicle's mixing cycle, it is possible to determine the air pollutant emissions generated during the electricity generation stage. In view of the issues involved in the life cycle analysis of road vehicles, including electric vehicles, it should be noted that electric vehicles have lower air pollutant emissions over their whole LCA (Life Cycle Analysis) compared to petrol and diesel vehicles [2]. The largest percentage of air pollutant emissions as CO_2-equivalent over a vehicle's life cycle is related to fuel production and fuel consumption for vehicle propulsion. For conventional road vehicles, the most relevant emissions component as part of the LCA assessment is the production of conventional fuels and the emissions from the combustion of petrol, diesel, or gas. With regard to electric vehicles in terms of air pollutant emissions, a key issue is related to electricity generation, as well as its sources. Figure 5–8 presents the results of the air pollutant emissions tests of the electric vehicles mentioned in Table 2 in 2023, determined using the analytical method presented earlier.

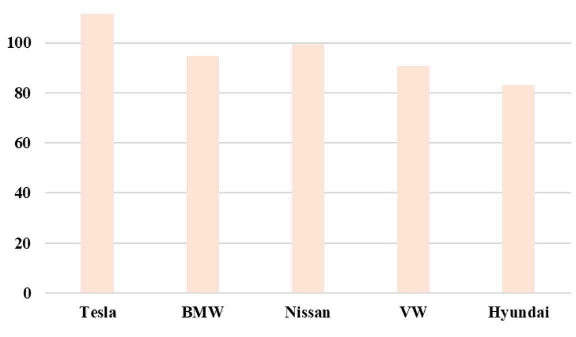

Fig. 5. CO_2 emissions of electric vehicles in 2023 [g/km]

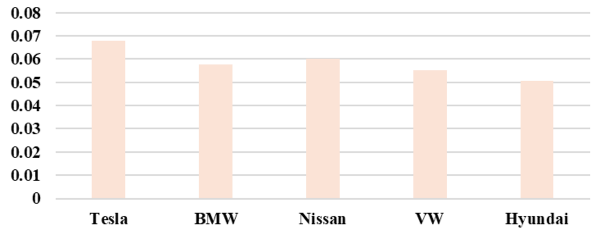

Fig. 6. SO_2 emissions of electric vehicles in 2023 [g/km]

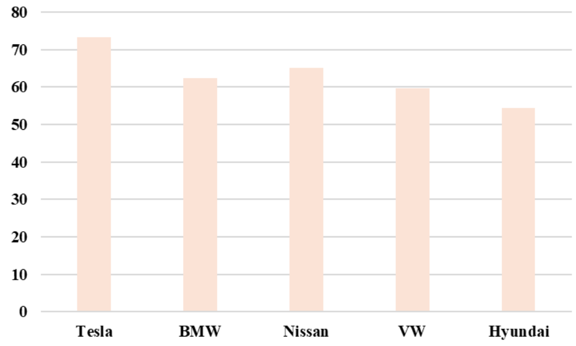

Fig. 7. NO_x emissions of electric vehicles in 2023 [g/km]

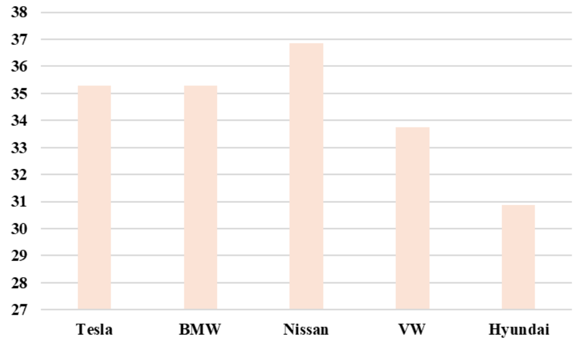

Fig. 8. CO emissions of electric vehicles in 2023 [g/km]

The CO_2 emissions are much higher than emissions of other compounds generated by vehicles, including NO_x and CO. However, the article presents CO and NO_x emissions due to the harmfulness of air pollutants generated in smaller quantities, and SO_2 emissions for electric vehicles.

The increasingly widespread use of electric vehicles in Poland and Europe represents an opportunity to reduce greenhouse gas emissions in the area of transport. Requirements for electric vehicles as well as charging stations are formulated to ensure safe use, monitoring of the charging process, and energy consumption [3]. In order for electric vehicles to be more widely used, charging stations on the TEN-T Trans-European Transport Network are required to be spaced at a maximum of every 60 km. The above can help reduce air pollutant emissions from road transport. An essential part of the infrastructure for powering electric vehicles is the power grids, of which, according to the Supreme Audit Office's reports, 90% of high-voltage power lines are more than 10 years old, with 43% – more than 40 years old. Low-voltage lines were in operation for the shortest time period, although still 32% of them had been in operation for more than 40 years [3]. In addition to lower air pollutant emissions, incentives for purchasing an electric vehicle can include lower insurance rates, lower electricity prices, attractive subsidy offers, concessions, and exemptions when driving in urban areas. In order to think about the widespread use of electric cars, the charging network needs to be increased by as much as six times by 2035 [3]. According to the IEA (International Energy Agency), if battery cars continue to develop at the current rate, their share of the global market should already reach 50% in the next decade.

As indicated earlier, due to the change in Poland's energy mix over recent years, the emissions of the individual compounds monitored by KOBIZE have changed. With emissions tables [22], it is possible to determine the rate of change of vehicle emissions over time for electric vehicles. To illustrate this phenomenon, two electric vehicles were used for the purpose of this paper, i.e., the VW ID.3 [32] and Nissan Leaf [29]. The power of the VW ID.3 vehicle was 170 kW, with a range of up to 388 km. Energy consumption was 152 Wh/km. The power of the Nissan Leaf vehicle was 150 kW, with a range of up to 285 km. Energy consumption was 166 Wh/km. The change in air pollutant emissions determined using the early analytical method described applies to carbon dioxide, nitrogen oxides and carbon monoxides are shown in Fig. 9 and Fig. 10.

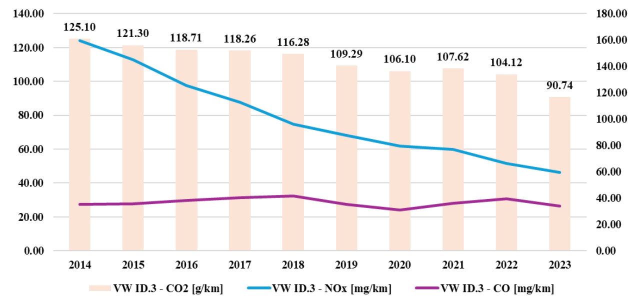

Fig. 9. Change in air pollutant emissions of VW ID.3 from 2014 to 2023, own elaboration

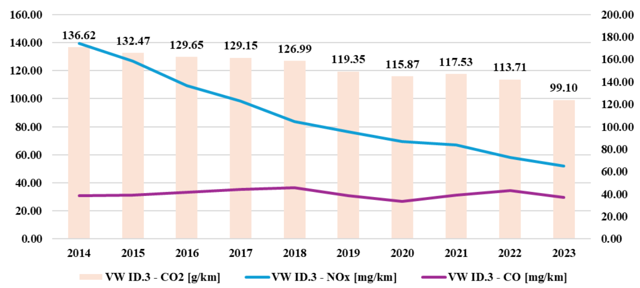

Fig. 10. Change in air pollutant emissions of Nissan Leaf from 2014 to 2023

Analysing the historical KOBIZE emissions data, for the VW ID.3 and the Nissan Leaf, assuming the current technical parameters for energy consumption between 2014 and 2024 for the above-mentioned vehicles, it should be noted that in the past decade there has been a decrease of 27% in CO_2 emissions, 63% in nitrogen oxides and 5% in carbon monoxide. A change in Poland's energy mix is therefore responsible for reducing EV emissions. It can therefore be assumed that the transfer of electricity production in Poland to renewable energy sources or nuclear energy will allow for even more significant reductions in emissions. This will enable the operation of electric vehicles to be referred to as zero-emission vehicle operation. Until this happens, it is possible to refer to electric vehicles as low-emission vehicles.

As part of the emissions testing of hybrid vehicles, air pollutant emissions were measured for the Kia Niro, manufacturing year 2022, 1.6 petrol engine, plug-in type, with a total power of nearly 105 HP [28]. In terms of hybrid vehicles, the analysis of fuel consumption and energy requirements is also an important issue [27]. Cumulative fuel consumption increases with increasing mileage, but the increase is not a linear function. Similar observations were made in terms of air emissions of vehicles with diesel engines [15, 16]. Pollutant emissions increased with operating age, but this was not an increase that could be described by a linear function. Detailed results of RDE tests of air pollutants for the Kia Niro vehicle in urban, suburban, motorway, and RDE modes are shown in Fig. 11, Fig. 13, and Fig. 15.

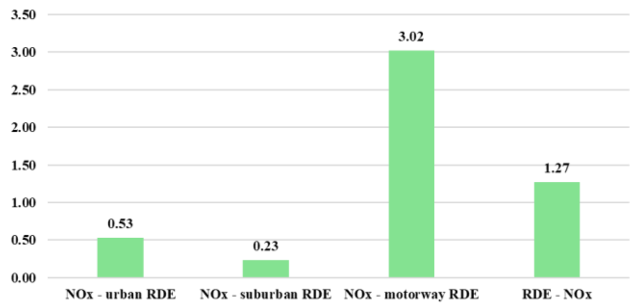

Fig. 11. NO_x emissions of the Kia Niro, RDE test [mg/km]

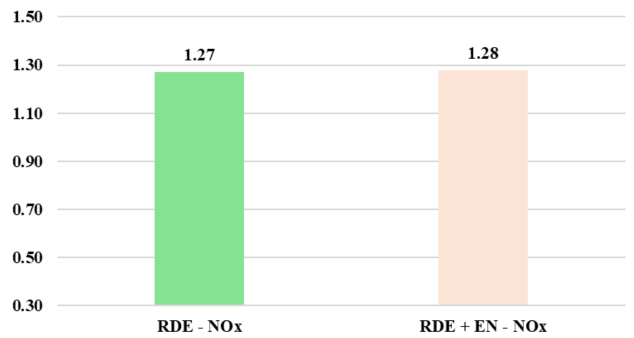

Fig. 12. NO_x emissions of the Kia Niro, RDE test and RDE + EN emissions [mg/km]

The air pollutant emissions of a hybrid vehicle are those from the combustion of fuel while the vehicle is running, shown in Fig. 11, Fig. 13, and Fig. 15, as well as emissions including air pollutants generated from electricity generation, designated RDE + EN in Fig. 12, Fig. 14, and Fig. 16. The emissions marked as RDE + EN on Fig. 12, 14, and 16 are the emissions generated by the hybrid vehicle during the road test from combustion fuel, plus the emissions resulting from the electricity consumed by the hybrid vehicle during the road test. The energy marked as EN in the figures indicates emissions from energy drawn from the electric network by the hybrid vehicle.

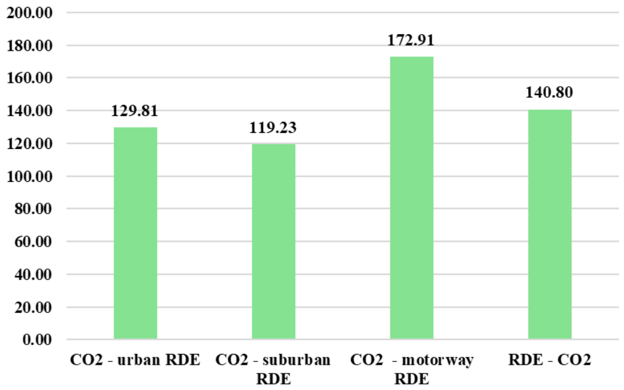

Fig. 13. CO_2 emissions of the Kia Niro, RDE test [mg/km]

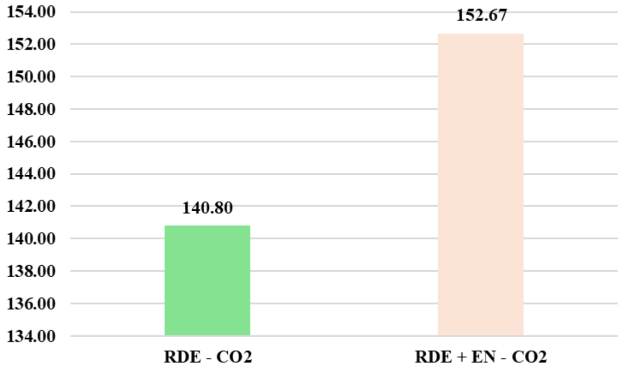

Fig. 14. CO_2 emissions of the Kia Niro, RDE test and RDE + EN emissions [mg/km]

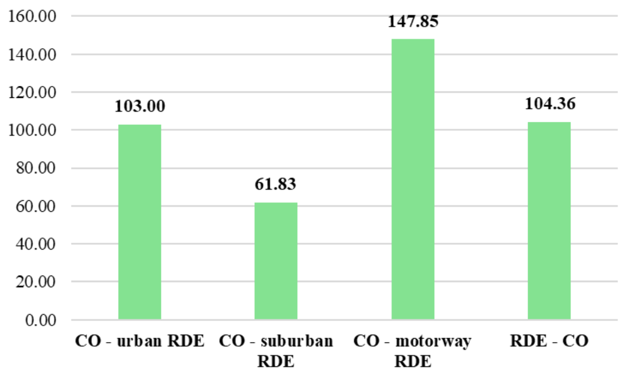

Fig. 15. CO emissions of the Kia Niro, RDE test [mg/km]

The air pollutant emissions of the hybrid vehicle, including those from electricity generation, contribute slightly to the higher total emissions found in the road tests. The above analyses related to determining the impact of emissions from electricity generation on the emissions of the hybrid vehicle were carried out using the analytical method indicated above and the air pollutant emissions from 2023 published by KOBIZE and shown in Table 1.

The Kia Niro hybrid vehicle's carbon dioxide emissions in the RDE road test were 140.80 g/km and, including emissions from electricity generation, amounted to 152.67 mg/km. This represents an increase in carbon dioxide emissions of around 8%. The nitrogen oxide emissions of the Kia Niro hybrid vehicle in the RDE road test were 1.27 mg/km and, including emissions from electricity generation, amounted to 1.28 mg/km. This represents an increase in nitrogen oxide emissions of around 1%. The carbon monoxide emissions of the Kia Niro hybrid vehicle in the RDE road test were 104.36 mg/km, and including emissions from electricity generation, also amounted to 104.36 mg/km.

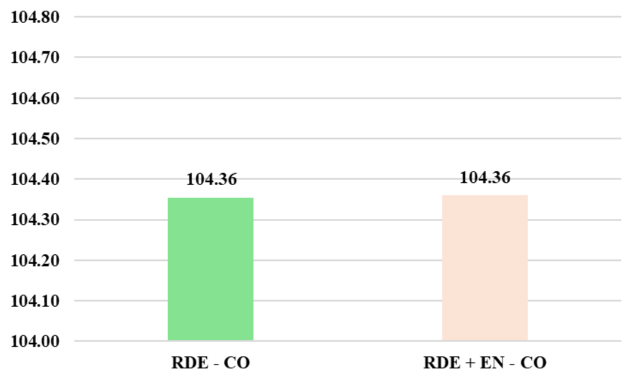

Fig. 16. CO emissions of the Kia Niro, RDE test, and RDE + EN emissions [mg/km]

4. Conclusions

The increasingly widespread use of electric vehicles in Poland and Europe represents an opportunity to reduce greenhouse gas emissions in the area of transport. An analytical method can be used to determine the emissions of electric vehicles, taking into account data from the general reports prepared by KOBIZE [22]. Knowing the energy consumption during the electric vehicle's mixing cycle, it is possible to determine the air pollutant emissions generated during the electricity generation stage. Analysing the historical KOBIZE emissions data, for the VW ID.3 and the Nissan Leaf, assuming the current technical parameters for energy consumption between 2014 and 2024 for the above-mentioned vehicles, it should be noted that the past decade featured a decrease of 27% in CO_2 emissions, 63% in nitrogen oxides and 5% in carbon monoxide. A change in Poland's energy mix is therefore responsible for reducing EV emissions. It can therefore be assumed that the transfer of electricity production in Poland to renewable energy sources or nuclear energy will allow for even more significant reductions in emissions. This will enable the operation of electric vehicles to be referred to as zero-emission vehicle operation. Until this happens, it is possible to refer to electric vehicles as low-emission vehicles. The proposed analytical method for determining the air pollutant emissions of electric vehicles makes it possible to observe changes in pollutant emissions over time, taking into account the changing electricity production mix in Poland and scenarios for organizing transport systems with electric vehicles [7].

For hybrid vehicles, RDE measurements of air pollutant emissions can be corrected using the analytical method to the extent that they relate to the measurement of emissions associated with electricity generation. The Kia Niro hybrid vehicle's carbon dioxide emissions in the RDE road test were 140.80 g/km and, including emissions from electricity generation, amounted to 152.67 mg/km. This represents an increase in carbon dioxide emissions of around 8%. The nitrogen oxide emissions of the Kia Niro hybrid vehicle in the RDE road test were 1.27 mg/km and, including emissions from electricity generation, amounted to 1.28 mg/km. This represents an increase in nitrogen oxide emissions of around 1%. The carbon monoxide emissions of the Kia Niro hybrid vehicle in the RDE road test were 104.36 mg/km, and including emissions from electricity generation, also amounted to 104.36 mg/km.

Acknowledgements

This paper was prepared as part of a research project in support of scientific activities in the discipline of Civil Engineering and Transport entitled "Investigating the phenomenon of ageing transport modes in the context of the environmental impact of vehicles".

Nomenclature

HEV	hybrid electric vehicle
IEA	International Energy Agency
KOBIZE	National Centre for Emissions Management
LCA	life cycle analysis
mHEV	mild hybrid electric vehicle
NEDC	New European Driving Cycle
PHEV	plug-in hybrid electric vehicle
RES	renewable energy sources
RDE	measurement of real driving emissions
TTW	tank to wheel
WLTP	Worldwide Harmonized Light-Duty Vehicles Test Procedure
WTT	well to tank

Bibliography

[1] Dziubak T, Ślęzak M. Characteristics of pollutants emitted by motor vehicles and their impact on the environment and engine operation. Combustion Engines. 2025;200(1):37-55. https://doi.org/10.19206/CE-194628

[2] Hill N. Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA. 2020. https://op.europa.eu/en/publication-detail/-/publication/1f494180-bc0e-11ea-811c-01aa75ed71a1

[3] Idzior M. Implications of power infrastructure development for the electromobility of the motor vehicle market in Poland. Logistics Systems in Theory and Practice 2024 Conference, Warsaw.

[4] Izdebski M, Jacyna M, Bogdański J. Minimisation of the energy expenditure of electric vehicles in municipal service companies, taking into account the uncertainty of charging point operation. Energies. 2024;17(9):2179. https://doi.org/10.3390/en17092179

[5] Jacyna M, Wasiak M, Lewczuk K, Kłodawski M. Simulation model of transport system of Poland as a tool for developing sustainable transport. Archives of Transport. 2014;31(3):23-35. https://doi.org/10.5604/08669546.1146982

[6] Jacyna M, Żochowska R, Sobota A, Wasiak M. Scenario analyses of exhaust emissions reduction through the introduction of electric vehicles into the city. Energies. 2021; 14(7):2030. https://doi.org/10.3390/en14072030

[7] Jacyna M, Żochowska R, Sobota A, Wasiak M. Decision support for choosing a scenario for organizing urban transport system with share of electric vehicles. Scientific Journal of the Silesian University of Technology. Series Transport. 2022;117:69-89 https://doi.org/10.20858/sjsutst.2022.117.5

[8] Jacyna-Gołda I, Izdebski M, Szczepański E, Gołda P. The assessment of supply chain effectiveness. Archives of Transport. 2018;45(1):43-52. https://doi.org/10.5604/01.3001.0012.0966

[9] Lasota M, Zabielska A, Jacyna M, Gołębiowski P, Żochowska R, Wasiak M. Method for delivery planning in urban areas with environmental aspects. Sustainability. 2024;16(4): 1571. https://doi.org/10.3390/su16041571

[10] Lasota M, Zabielska A, Jacyna M, Żak J. Research and analysis of the operation of vehicles with various propulsion systems, including costs and CO_2 emissions. Combustion Engines. 2023;4(195):3-13. https://doi.org/10.19206/CE-169845

[11] Mądziel M, Campisi T, Jaworski A, Tesoriere G. The development of strategies to reduce exhaust emissions from passenger cars in Rzeszow city – Poland, a preliminary assessment of the results produced by the increase of e-fleet. Energies. 2021;14(4):1046. https://doi.org/10.3390/en14041046

[12] Merkisz J, Sordyl A, Chłopek Z. Non-repeatability of the WLTP vehicle test results. Archives of Transport. 2024; 71(3):25-49. https://doi.org/10.61089/aot2024.fjw8a575

[13] Pielecha J, Skobiej K, Kurtyka K. Exhaust emissions and energy consumption analysis of conventional, hybrid, and electric vehicles in real driving cycles. Energies. 2020;13(23):6423. https://doi.org/10.3390/en13236423

[14] Pryciński P, Pielecha P, Korzeb J, Pielecha J, Kostrzewski M, Eliwa A. Air pollutant emissions of passenger cars in Poland in terms of their environmental impact and type of energy consumption. Energies. 2024;17(21):5357. https://doi.org/10.3390/en17215357

[15] Pryciński P, Pielecha J, Korzeb J, Jachimowski R, Pielecha P. Impact of vehicle aging and mileage on air pollution emissions. Energies. 2025;18(4):939. https://doi.org/10.3390/en18040939

[16] Pryciński P, Korzeb J, Pielecha J: Research on the impact of vehicle aging on the amount of air pollution emissions. Journal of Konbin. 2025;55(1):105-120. https://doi.org/10.5604/01.3001.0055.0625

[17] Rudyk T, Szczepański E, Jacyna M. Safety factor in the sustainable fleet management model. Archives of Transport. 2019;49(1):103-114. https://doi.org/10.5604/01.3001.0013.2780

[18] Rymaniak Ł, Kamińska M, Szymlet N, Grzeszczyk R. Analysis of harmful exhaust gas concentrations in cloud behind a vehicle with a spark ignition engine. Energies. 2021;14(6): 1769. https://doi.org/10.3390/en14061769

[19] Skobiej K. A review of hydrogen combustion and its impact on engine performance and emissions. Combustion Engines. 2025;200(1):64-70. https://doi.org/10.19206/CE-195470

[20] Suarez-Bertoa R, Astorga C, Franco V, Kregar Z, Valverde V, Clairotte M et al. Technical report by the Joint Research Centre (JRC). On-road vehicle emissions beyond RDE conditions. 2019. https://publications.jrc.ec.europa.eu/repository/handle/JRC115979

[21] Regulation of the Commission (EU) no. 2016/427 of 10 March 2016 amending Regulation (EC) no. 692/2008 as regards emissions from light passenger and commercial vehicles.
[22] Report: Air pollutant emissions from electricity production in Poland. 2025. KOBIZE. https://www.kobize.pl/pl/fileCategory/id/28/wskazniki-emisyjnosci
[23] Report: Automotive Industry 2024/2025. 2025. Polish Automotive Industry Association. https://www.pzpm.org.pl/en/Automotive-market/Reports/PZPM-Automotive-Industry-Report-2024-2025
[24] Report: Integrated Impact Report of Polskie Sieci Elektroenergetyczne S.A. 2025. PSE S.A. https://api-raport.pse.pl/uploads/PSE-Zintegrowany_Raport_Wplywu_2023.pdf
[25] Report: The structure of electricity production in the European Union. 2025. Council of the EU. https://www.consilium.europa.eu/pl/infographics/how-is-eu-electricity-produced-and-sold/#0
[26] Report: The structure of electricity production in Poland. 2025. CIRE. https://www.cire.pl/strony/struktura-i-produkcja-energii-elektrycznej-w-polsce
[27] Sitnik L, Ivanov Z, Sroka Z. Energy demand assessment for long term operation of hybrid electric vehicles. 2020 IOP Conf Ser: Mater Sci Eng. 2020;1002(1):012026. https://doi.org/10.1088/1757-899X/1002/1/012026
[28] Website: Motovolt. 2025. https://motorvolt.pl/baza-samochodow-elektrycznych
[29] Website: Nissan. 2025. https://www-europe.nissan-cdn.net/content/dam/Nissan/pl/brochures/Techdata/leaf-dane-techniczne.pdf
[30] Website: NFOSiGW. 2025. OurEvehicle programme. https://www.gov.pl/web/nfosigw/program-naszeauto-do-40-tys-zl-doplaty-do-samochodu-elektrycznego
[31] Website: Sany. 2025. https://www.sanyglobal.com/product/truck/semi-trailer_tractor/138/
[32] Website: Volkswagen. 2025. https://www.volkswagen.pl/
[33] Zimakowska-Laskowska M, Kozłowski E, Laskowski P, Wiśniowski P, Świderski A, Orynycz O. Vehicle exhaust emissions in the light of modern research tools: synergy of chassis dynamometers and computational models. Combustion Engines. 2025;200(1):145-154. https://doi.org/10.19206/CE-201224

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