

**The European Commission's
science and knowledge service**

Joint Research Centre

Research Activity Overview

Georgios Fontaras



European
Commission

Vehicle emissions & market surveillance

Performed numerous tests on different vehicle types as part of regular JRC activity, specific policy support, and market surveillance

Numerous publications on emissions related issues



JRC SCIENCE FOR POLICY REPORT

Joint Research Centre 2017 light-duty vehicles emissions testing

Contribution to the EU market surveillance: testing protocols and vehicle emissions performance

M. Chiarotte, V. Valverde, P. Bonnel, B. Giachisari, M. Carraro, M. Oltus, G. Fontaras, J. Pavoni, G. Martini, A. Krasenbrink, R. Suarez Berboa



atmosphere

Emission Factors Derived from 13 Euro 6b Light-Duty Vehicles Based on Laboratory and On-Road Measurements

Victor Valverde*, Benat Adria Mora, Michail Chiarotte, Jelica Pavoni, Ricardo Suarez-Berboa, Barouch Giachisari, Covadonga Astorga-Lorena and Georgios Fontaras*
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Abstract: Tailpipe emissions of a pool of 13 Euro 6b light-duty vehicles (eight diesel and five gasoline-powered) were measured over an extensive experimental campaign that included laboratory (chassis dynamometer), and on-road tests (using a portable emissions measurement system). The New European Driving Cycle (NEDC) and the Worldwide harmonized Light-duty vehicles Test Cycle (WLTC) were driven in the laboratory following standard and extended testing procedures (such as low temperature, use of auxiliaries, modified speed ramp). On-road tests were conducted in real traffic conditions, within and outside the boundary conditions of the regulated European Road Driving Emissions (RDE) test. Nitrogen oxides (NO_x), carbon monoxide (CO), total hydrocarbons (THC), and carbon dioxide (CO₂) emission factors were developed considering the whole cycle, their sub-cycles, and the first 300 seconds of each test to assess the cold start effect. Despite complying with the NEDC type approval NO_x limit, diesel vehicles emitted, on average, over the WLTC and the RDE 21 and 67 times more than the standard limit, respectively. Diesel vehicles equipped with only a Lean NO_x trap (LNT) averaged six and two times more emissions over the WLTC and the RDE, respectively, than diesel vehicles equipped with a selective catalytic reduction (SCR) catalyst. Gasoline vehicles with direct injection (DI) emitted eight times more NO_x than those with port fuel injection (PFI) on RDE tests. Large NO_x emissions on the urban section were also recorded for GDI (122 mg/km). Diesel particle filters were mounted on all diesel vehicles, resulting in low particle number emission (10⁹ #/km) over all testing conditions including low temperature and high dynamism. GDI (100 #/km) and PFI (30 #/km) had PN emissions that were, on average, two and one order of magnitude higher than for diesel vehicles, respectively, with significant contribution from the cold start. PFI yielded high CO emissions factors under high load operation reaching on average 2.2 g/km and 1.6 g/km on WLTC and high and RDE, respectively. The average on-road CO₂ emissions were 33% and 41% higher than the declared CO₂ emissions at type-approval for diesel and gasoline vehicles, respectively. The use of auxiliaries (AC and lights on) over the NEDC led to an increase of 20% of CO₂ emissions for both diesel and gasoline vehicles. Results for NO_x, CO, and CO₂ were used to derive average annual emission factors that are in good agreement with the emission factors proposed by the EMEP/EEA guideline.

Keywords: Emission factors; light-duty vehicles; Real Driving Emissions; NEDC; WLTC; PEMS; CO₂; NO_x; PN

atmosphere 2019, 11, 241; doi:10.3390/atmos11050241



From lab-to-road & vice-versa: Using a simulation-based approach for predicting real-world CO₂ emissions*

Stefanos Triakakis^{1,2}, Georgios Fontaras^{1,2}, Jan Dornhoff³, Victor Valverde⁴, Dimitris Koronas⁵, Biagio Gufo⁶, Peter Mock⁷, Zisis Samaras⁸

Abstract: CO₂ emissions of light-duty vehicles are certified on standardized, laboratory-based conditions and reported to the consumer. Such values are specific operating conditions that differ from what an individual driver experiences. Vehicle emissions on the road are highly dependent on driver and in-vehicle variables. This study investigates the potential of using a simulation-based approach for calculating CO₂ emissions over real-world operation, when limited information and data are available. The methodology implemented in European vehicle certification regulations in 2017 is used as a basis. Some vehicles were tested over multiple on-road trips and in some cases on a chassis dynamometer. The available data on the energy of the operations were only limited information for the vehicle and its components on road. To simplify the model was adopted on test data. The first case presented an over-engineered (ULEV) car equipped on the road, while the second case was a TIER1. When using WLTP for calculation, the average error dropped to -2.8% to -0.2%, and its standard deviation decreased to 2.0%. When performing on-road tests, the average error was 0.5% for the on-road test and 4.5% for the WLTP.

1. Introduction

Reducing CO₂ emissions and energy consumption from the road transport sector is of high importance to the European member states for fulfilling their commitments to reduce their greenhouse gas (GHG) emissions and bring up to the targets of the Paris Agreement on climate change mitigation. In Europe, transport accounts for roughly one-fifth of the total GHG emissions, the majority of which originates from road transport (European Commission, 2018). In the European Union (EU), where a greenhouse gas emissions cap will still exist [1]. Given this, the EU adopted policies and other initiatives, aiming to limit CO₂ emissions from transport. In particular, for road transport, these include emissions monitoring, promoting technologies that reduce the CO₂ emission

* The views expressed in this paper are purely those of the authors and may not be shared with or attributed to an official position of the European Commission.

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Real world emissions performance of heavy-duty Euro VI diesel vehicles

Theodoros Grigoratos¹, Georgios Fontaras¹, Barouch Giachisari¹, Nikiforos Zacharou²

Abstract: Despite the introduction of Euro VI (2015) emission limits for diesel engines, the real world emissions performance of heavy-duty Euro VI diesel engines remains to be seen. This is one of the main objectives of the current study. The study focuses on the real world emissions performance of heavy-duty Euro VI diesel engines. The study focuses on the real world emissions performance of heavy-duty Euro VI diesel engines. The study focuses on the real world emissions performance of heavy-duty Euro VI diesel engines.

1. Introduction

Air pollution has a detrimental effect on human health, natural environment, security and quality of life. In addition, it also has a significant impact on the European economy. The main reason for this is the increase in the number of heavy-duty Euro VI diesel engines. The study focuses on the real world emissions performance of heavy-duty Euro VI diesel engines. The study focuses on the real world emissions performance of heavy-duty Euro VI diesel engines.

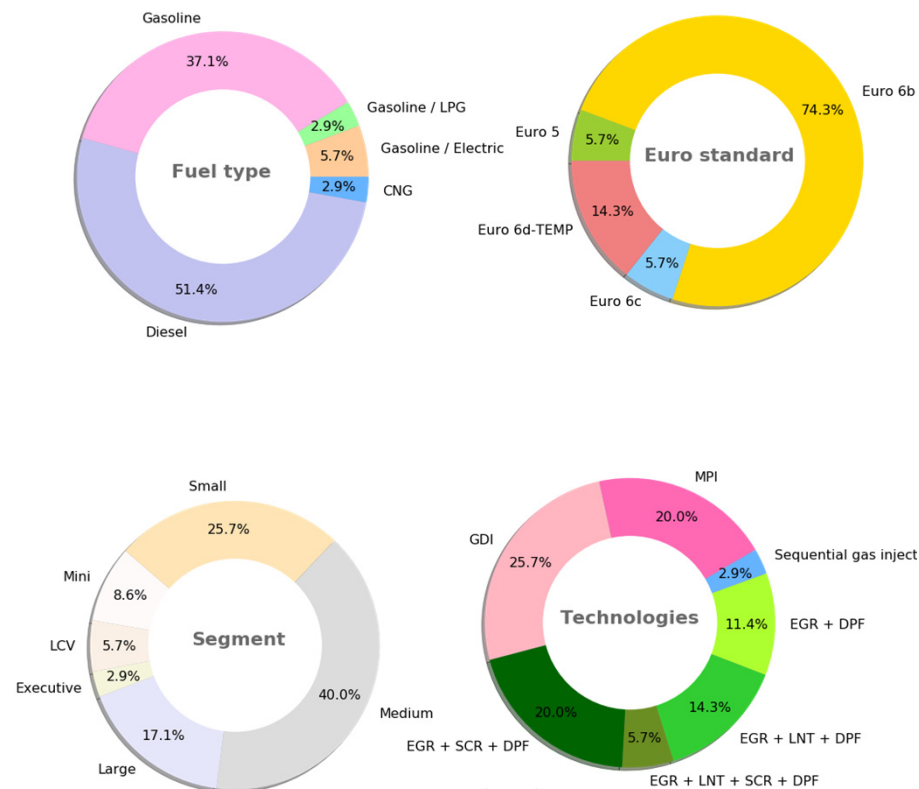
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atmosphere 2019, 11, 241; doi:10.3390/atmos11050241

Market Surveillance

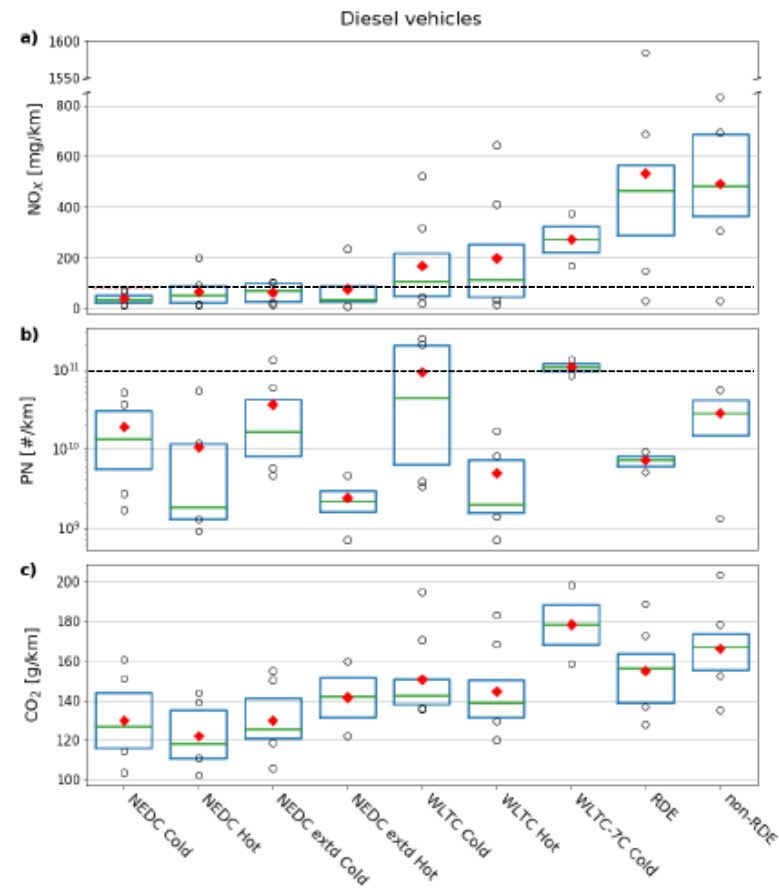
- MS pilot 2017 & 2018; 35 vehicles tested
- Multiple types of Tests

Type of Test	Objectives
NEDC Cold	Vehicle emissions compliance under standard conditions
NEDC Hot	Emissions performance with hot engine, to check for a potential timer or vehicle conditioning triggering AES ⁴
NEDC w/o preconditioning Cold	Emissions performance on a cold started NEDC driving cycle without pre-conditioning of the vehicle, to check for the potential vehicle conditioning triggering AES
NEDC Repeated Hot	Emissions performance with hot engine (without turning off the engine between the two tests), to check for a potential timer or distance windows triggering AES
Modified NEDC Cold +10% Speed	Vehicle emissions on a modified NEDC driving cycle, to check for a potential speed or distance windows triggering AES
Modified NEDC Cold -10% Speed	Vehicle emissions on a modified NEDC driving cycle, to check for a potential speed window triggering AES
NEDC hot with additional engine loads (A/C and lights)	Emissions performance with hot engine and additional engine loads (A/C and lights), to check for a potential use of vehicle systems triggering AES
NEDC +10°C Cold	Emissions performance at low ambient temperature, to check for a potential thermal window triggering AES
NEDC +30°C Cold	Emissions performance at high ambient temperature (higher than 30°C ⁵), to check for a potential thermal window triggering AES
WLTC Cold	Emissions performance on cold started WLTC to check for a potential timer, vehicle conditioning, as well as speed or distance windows triggering AES.
WLTC Hot	Emissions performance on hot started WLTC to check for a potential timer, vehicle conditioning, as well as speed or distance windows triggering AES.
RDE	Emissions performance on road, to check for ECS functioning under uncontrolled conditions, beyond the NEDC conditions



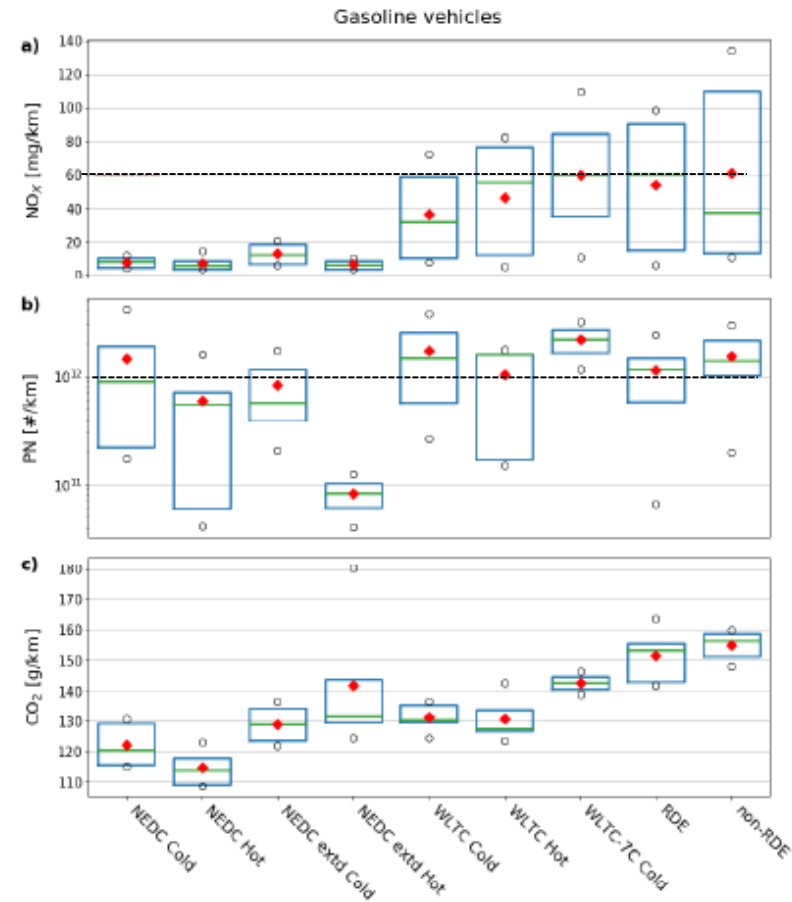
Emission factors from LDVs – Diesel vehs.

- Results suggest downward trends – exceedances appeared under certain conditions
- EFs from the EEA inventory guidebook provide accurate estimates
- Could benefit from on-road tests within and outside RDE boundaries particularly for post Euro 6b technology.



Emission factors from LDVs – Gasoline vehs.

- Results show compliance over most conditions
- GDI high PN emissions
- EFs from the EEA inventory guidebook provide accurate estimates
- CO₂ emissions comparable to those of diesel vehicles



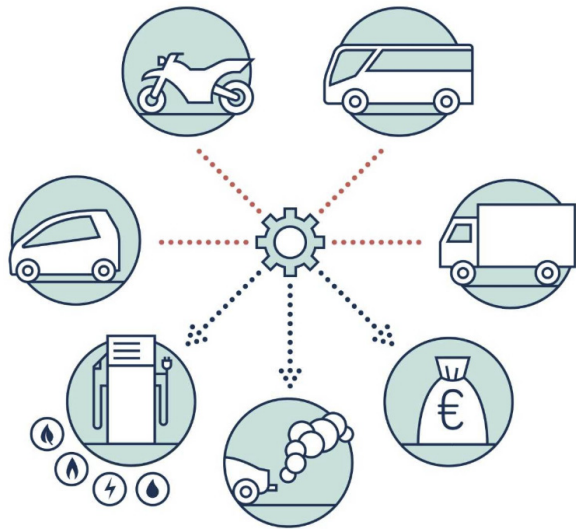
Emission factors from HDVs

Overall and breakdown to different speed classes emissions of all examined vehicles.

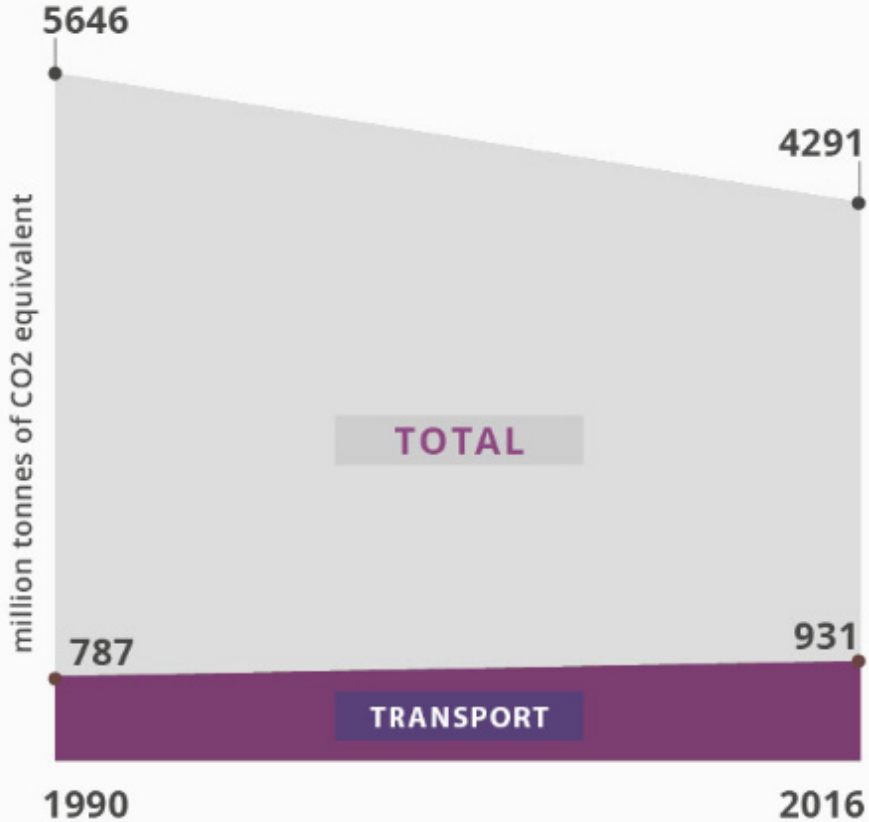
	CO2 [g/kWh]	CO [g/kWh]	NOx [g/kWh]	THC [g/kWh]	PN [#kWh]	CO2 [g/km]	CO [g/km]	NOx [g/km]	THC [g/km]	PN [#km]
Vehicle #1	621.8 ± 4.8	1.02 ± 0.33	0.16 ± 0.05	0.11 ± 0.02	5.6 ± 1.0E+10	750.1 ± 14.6	1.22 ± 0.37	0.19 ± 0.06	0.14 ± 0.03	6.8 ± 1.3E+10
Low Speed	691.3 ± 22.0	1.37 ± 0.43	0.80 ± 0.20	0.14 ± 0.03	8.5 ± 7.8E+10	2414.9 ± 105.9	4.73 ± 1.34	2.78 ± 0.54	0.50 ± 0.10	3.1 ± 3.0E+11
Medium Speed	565.9 ± 3.3	0.95 ± 0.32	0.15 ± 0.05	0.10 ± 0.02	3.0 ± 0.4E+10	909.8 ± 26.5	1.52 ± 0.51	0.26 ± 0.07	0.16 ± 0.04	4.9 ± 0.7E+10
High Speed	635.7 ± 9.1	1.00 ± 0.32	0.08 ± 0.04	0.11 ± 0.02	6.0 ± 0.8E+10	646.2 ± 20.5	1.01 ± 0.29	0.08 ± 0.03	0.11 ± 0.02	6.1 ± 1.1E+10
Vehicle #2	643.4 ± 0.8	0.75 ± 0.17	0.28 ± 0.07	0.07 ± 0.01	n/a	554.5 ± 6.5	0.65 ± 0.14	0.24 ± 0.06	0.06 ± 0.01	n/a
Low Speed	804.6 ± 27.2	1.17 ± 0.17	0.69 ± 0.17	0.10 ± 0.01	n/a	1325.1 ± 22.5	1.92 ± 0.22	1.13 ± 0.22	0.17 ± 0.02	n/a
Medium Speed	646.8 ± 11.8	0.79 ± 0.19	0.50 ± 0.11	0.08 ± 0.01	n/a	548.2 ± 4.5	0.67 ± 0.15	0.43 ± 0.10	0.07 ± 0.01	n/a
High Speed	631.2 ± 3.1	0.72 ± 0.17	0.21 ± 0.05	0.07 ± 0.01	n/a	528.4 ± 9.6	0.60 ± 0.13	0.17 ± 0.04	0.06 ± 0.01	n/a
Vehicle #3	662.0 ± 1.8	0.80 ± 0.08	0.78 ± 0.13	0.11 ± 0.01	6.5 ± 0.4E+10	831.8 ± 15.9	1.01 ± 0.13	0.98 ± 0.17	0.13 ± 0.01	8.1 ± 0.4E+10
Low Speed	1108.6 ± 86.0	1.90 ± 0.15	2.58 ± 0.21	0.25 ± 0.05	1.2 ± 0.7E+11	2856.0 ± 261.4	4.88 ± 0.44	6.64 ± 0.21	0.63 ± 0.11	3.0 ± 1.4E+11
Medium Speed	669.9 ± 3.7	0.83 ± 0.09	0.93 ± 0.10	0.10 ± 0.02	3.5 ± 0.1E+10	956.5 ± 12.4	1.18 ± 0.10	1.33 ± 0.12	0.14 ± 0.03	5.0 ± 0.0E+10
High Speed	642.0 ± 3.5	0.75 ± 0.08	0.67 ± 0.12	0.10 ± 0.00	6.9 ± 0.8E+10	769.4 ± 15.6	0.90 ± 0.12	0.80 ± 0.16	0.12 ± 0.00	8.2 ± 0.8E+10
Vehicle #4	621.3 ± 2.0	0.76 ± 0.21	0.09 ± 0.01	0.10 ± 0.03	n/a	749.4 ± 6.8	0.92 ± 0.26	0.10 ± 0.01	0.12 ± 0.03	n/a
Low Speed	729.3 ± 9.2	1.25 ± 0.33	0.10 ± 0.00	0.13 ± 0.03	n/a	2637.7 ± 123.5	4.55 ± 1.47	0.37 ± 0.02	0.45 ± 0.10	n/a
Medium Speed	596.3 ± 7.0	0.91 ± 0.20	0.13 ± 0.02	0.10 ± 0.03	n/a	917.9 ± 58.2	1.40 ± 0.38	0.20 ± 0.04	0.16 ± 0.03	n/a
High Speed	619.2 ± 1.5	0.67 ± 0.20	0.07 ± 0.01	0.10 ± 0.02	n/a	657.0 ± 7.7	0.71 ± 0.20	0.07 ± 0.02	0.10 ± 0.03	n/a
Vehicle #5	708.4 ± 12.0	1.09 ± 0.40	0.37 ± 0.06	0.17 ± 0.01	n/a	689.5 ± 12.5	1.06 ± 0.37	0.36 ± 0.05	0.17 ± 0.01	n/a
Low Speed	981.6 ± 17.8	2.08 ± 0.64	2.05 ± 0.34	0.29 ± 0.02	n/a	2184.3 ± 119.8	4.59 ± 1.24	4.59 ± 1.09	0.65 ± 0.06	n/a
Medium Speed	661.3 ± 26.8	1.18 ± 0.40	0.33 ± 0.09	0.16 ± 0.01	n/a	766.5 ± 33.8	1.35 ± 0.41	0.39 ± 0.12	0.19 ± 0.01	n/a
High Speed	698.7 ± 11.1	0.99 ± 0.38	0.24 ± 0.08	0.16 ± 0.02	n/a	622.6 ± 10.4	0.88 ± 0.33	0.22 ± 0.07	0.15 ± 0.01	n/a

- Results in-line with emission inventories regarding NOx and particle number
- CO₂ emissions tend to be underestimated although loading plays a crucial role
- Issues identified with HC and CO but not considered important

CO₂ emissions & energy consumption



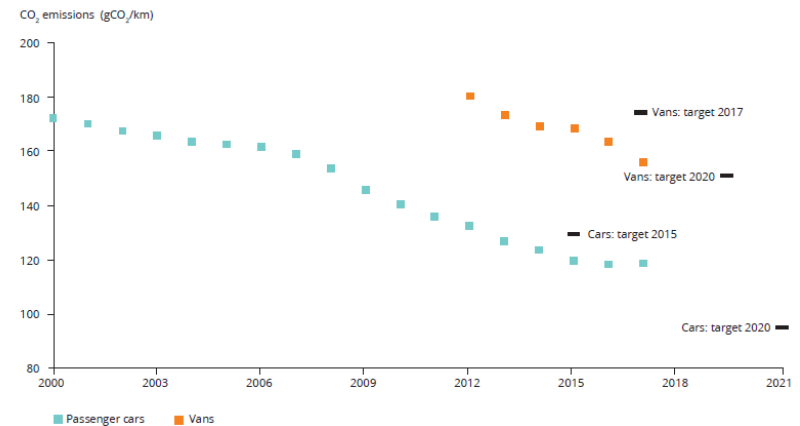
GREENHOUSE GAS EMISSIONS IN THE EU



94%
of the **transport**
greenhouse gas
emissions are
caused by
road transport

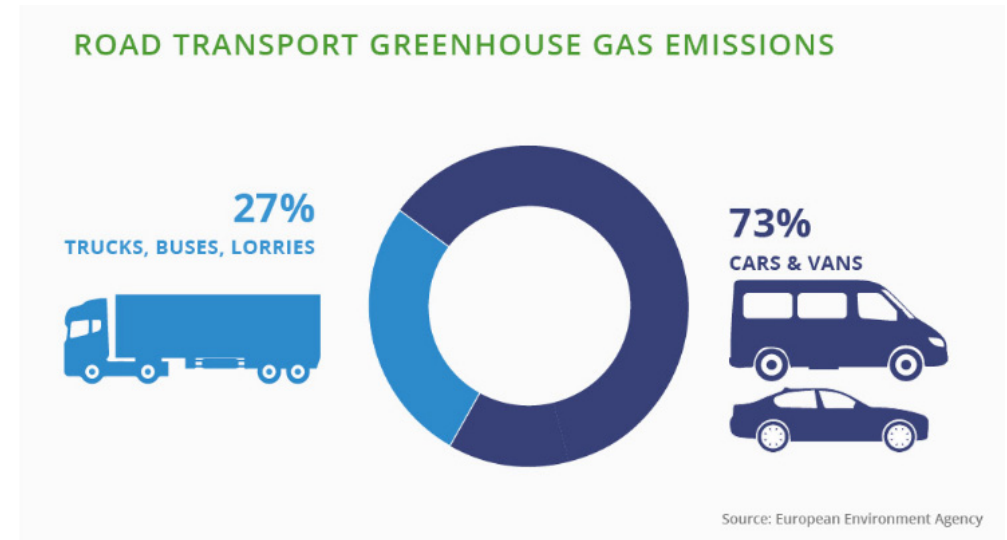
CO₂ & Greenhouse gas emissions post 2020

- GhG emissions and CO₂ will become a (very) hot topic in the years to come
- Recent data reported suggest a slowing down of CO₂ reduction rates
 - **New cycle**
 - **Stricter emissions control**
 - **Diesel share reduction**
- Additional efforts to be put on monitoring & reporting, accurate real world CO₂ estimations, conformity & compliance
- Necessity for new instruments for incentivizing CO₂ reductions, acceleration of technology uptake, and support of on-going efforts & investment at vehicle, infrastructure, and mobility level
- Interesting how OEMs & Institutions will react in the years to come



2019 – a pivotal year for vehicle CO₂ emissions

- Dec. 18 CO₂ emission targets for new LDVs
- Cars targets: 15% in 2025 and 37.5% in 2030, both relative to a 2021 baseline (WLTP)
- N1 vehicles: a 15% target for 2025 and a 31% target for 2030 (WLTP)
- Feb. 19, CO₂ standards for HDVs introduced for the first time in EU
- Reduce the average CO₂ emissions from the highest-emitting HDV segments by 15% in 2025 and by 30% in 2030
- Reduction relative to a baseline determined from 2019 and 2020 data
- VECTO used for certifying CO₂ emissions



LDV post 2020 targets framework

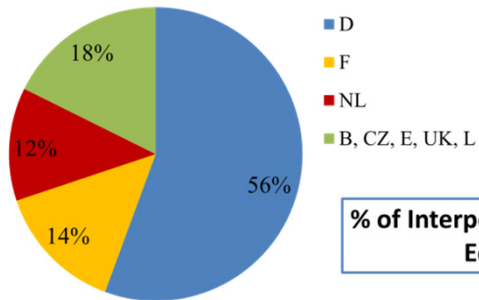
- **zero-emission vehicles** such as BEV or fuel cell vehicles
- **low-emission vehicles**, emissions of less than 50 g CO₂ per km
- **market surveillance mechanisms** for maintaining a reliable and trustworthy system
- **collection, publication, and monitoring of** real world fuel consumption data
- Compulsory standardised 'fuel consumption measurement devices' in new vehicles as of 2019 (**OBFCM**)
- **in-service conformity checks** will be introduced combined with correction mechanisms so that deviations are taken into account during the **compliance assessment**.

HDV CO₂ targets framework

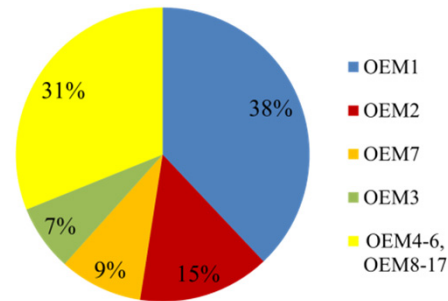
- **Zero** and **low emissions** vehicles
- Series of **incentives** to accelerate technology uptake
- Collect, publish and monitor **real-world fuel consumption data**
- Introduce in-service **conformity tests** and mandate the reporting of deviations and the introduction of a correction mechanism
- Apply **financial penalties** in case of non-compliance with the CO₂ targets
- In 2022, the scope will be extended to include **other vehicle types** such as smaller lorries, buses, coaches and trailers

JRC TA data collection and analysis project

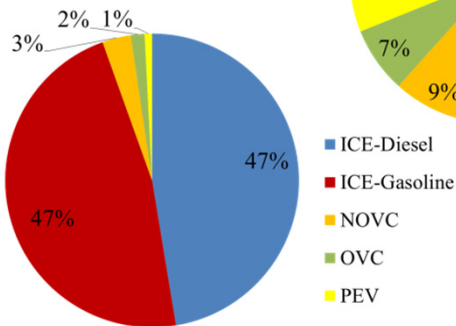
% of Interpolation (IP) families per Member State (MS).



% of Interpolation (IP) families per Original Equipment Manufacturer (OEM).



Engine Type.



Average (median, standard deviation) WLTP/NEDC CO₂ ratio for different vehicle technologies.

Engine Type	Vehicle HIGH (H)	Vehicle LOW (L)
ICE-Diesel	1.27 (1.26, ±0.07)	1.18 (1.18, ±0.05)
ICE-Gasoline	1.19 (1.17, ±0.09)	1.14 (1.14, ±0.07)
HEV	1.18 (1.21, ±0.07)	1.08 (1.06, ±0.13)
PHEV-CS	1.25 (1.24, ±0.10)	1.19 (1.16, ±0.10)
PHEV-Weight. Comb.	1.09 (1.25, ±0.37)	0.98 (1.09, ±0.35)

TRIMIS: Background



Transport Research and Innovation Monitoring and Information System (TRIMIS):

The analytical support tool for the establishment and implementation of the **Strategic Transport Research and Innovation Agenda (STRIA)**

STRIA was adopted by the EC in the May 2017 "Europe on the move" Package

Main objectives:

- Mapping **technology trends and R&I capacities** in transport
- Monitoring progress against targets set for **all transport sectors**
- Ensuring that **STRIA roadmaps** are implemented, monitored and updated



TRIMIS: Web-portal

Launched in September 2017

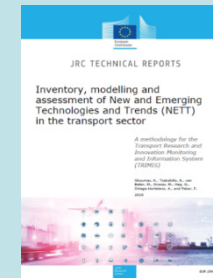
<https://trimis.ec.europa.eu>

- **Established Transport R&I portal** – ca. 1400 unique weekly visits
- **Transport R&I Database** - continuous update: ca. 7200 Projects and Programmes
- **Announcements** and **Events Calendar**

The screenshot shows the TRIMIS web-portal interface. At the top, there is a navigation menu with options: HOME, ROADMAPS, PROJECTS, PROGRAMMES, COUNTRY PROFILES, and BY ACCOUNT. Below the menu is a grid of eight project categories, each with a representative image and text: STRIA ROADMAPS, COOPERATIVE CONNECTED AND AUTOMATED TRANSPORT, TRANSPORT ELECTRIFICATION, VEHICLE DESIGN AND MANUFACTURING, LOW-EMISSION ALTERNATIVE ENERGY FOR TRANSPORT, NETWORK AND TRAFFIC MANAGEMENT SYSTEMS, SMART MOBILITY AND SERVICES, and INFRASTRUCTURE. Below the grid are sections for 'Projects', 'Programmes', 'Announcements', 'Highlights', 'Events', and 'Twitter'. The footer includes social media links, a 'PARTICIPATE' section, and 'TOOLS & LINKS'.

Policy support – Reporting on R&I

10 Science for Policy and Technical reports published by Apr. 2019



Other features

Monthly TRIMIS Newsletter

- Highlights, projects, events

Bi-monthly TRIMIS Digest

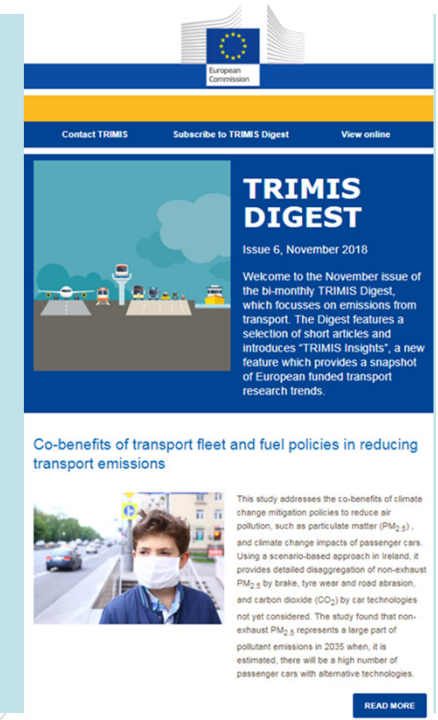
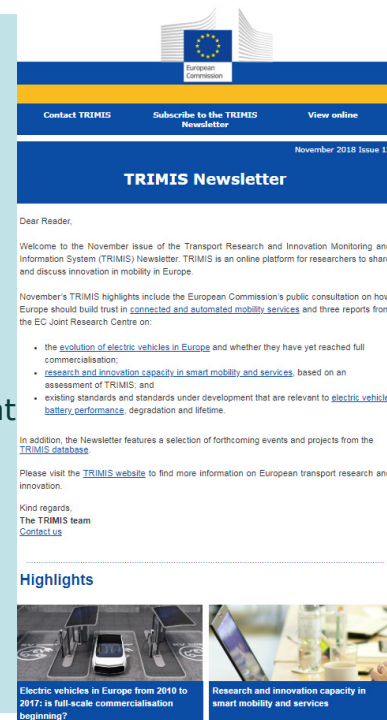
- Provides reviews of scientific research on selected topics

Database:

- Further expand with additional projects and programmes
- Towards a relational database, new links: MS, non-EU, pat

Content update:

- Update country profiles
- MS projects and programmes



Thank you for the attention!



<https://trimis.ec.europa.eu/>



EU-TRIMIS@ec.europa.eu



LinkedIn: **Transport Research and Innovation Monitoring and Information System (TRIMIS)**

Thank you for your attention!

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Special Thanks to Victor Valverde and Tasos Tsakalidis for their contributions