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**TNO report**

**TNO 2016 R10304v2**

# 2016 Emission factors for diesel Euro-6 passenger cars, light commercial vehicles and Euro-VI trucks

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# Samenvatting


**Emissiefactoren belangrijk voor betrouwbare luchtkwaliteitsberekeningen**
Gezonde lucht is belangrijk voor de gezondheid van iedereen. Om de luchtkwaliteit in Nederland te monitoren worden metingen uitgevoerd in het Landelijk Meetnet Luchtkwaliteit. Daarnaast worden op regelmatige basis luchtkwaliteitsberekeningen uitgevoerd. Voor deze berekeningen worden luchtkwaliteitsmodellen gebruikt, die op hun beurt moeten worden gevoed met zogenaamde invoerparameters.

De luchtkwaliteit wordt in Nederland voor een groot deel beïnvloed door het wegverkeer. Om de invloed van het wegverkeer op de luchtkwaliteit betrouwbaar te kunnen vaststellen, moeten de voornoemde luchtkwaliteitsmodellen worden voorzien van informatie over onder meer de gemiddelde wagenparksamenstelling (welke voertuigen rijden er in Nederland?), de gereden afstand (hoeveel kilometer leggen deze voertuigen gemiddeld af?) en informatie over de praktijkuitstoot per voertuig (hoeveel verontreinigende stoffen stoten deze voertuigen op de weg elke kilometer gemiddeld uit?). Informatie over de gemiddelde praktijkuitstoot per voertuig worden aangeduid als emissiefactoren.

Het wagenpark verandert; de rijdende voertuigen worden ouder, er worden nieuwe voertuigen verkocht, etc. Met een veranderend wagenpark veranderen ook de emissiefactoren van deze voertuigen. Om een betrouwbaar beeld van de luchtkwaliteit te kunnen garanderen, is het van groot belang dat de emissiefactoren up-to-date zijn. Bovendien worden emissiefactoren ook gebruikt om de stikstofdepositie in Nederland vast te stellen en baseert de Nederlandse emissieregistratie, die de totale jaar-op-jaar uitstoot in Nederland bepaalt, zich op emissiefactoren. Daarom worden emissiefactoren in Nederland jaarlijks zo nodig bijgesteld en opnieuw vastgesteld, op basis van nieuwe inzichten.

**Vaststelling emissiefactoren wegverkeer 2016**
Dit rapport beschrijft de emissiefactoren van personen- en bestelwagens en vrachtwagens en bussen in Nederland zoals die zijn vastgesteld voor 2016, en noemt de belangrijkste wijzigingen ten opzichte van de emissiefactoren van 2015. In 2015 heeft TNO een uitgebreid onderzoek uitgevoerd naar het rijgedrag van Nederlandse automobilisten. Rijgedrag werkt sterk door in de emissiefactoren. Daarom is in dit rapport een hoofdstuk gewijd aan dit onderwerp.

*Emissiefactoren 2016 voor personenwagens*
Een overzicht van de nieuwe emissiefactoren 2016 voor Euro-6 personenwagens is te vinden in het rapport. De emissiefactoren Euro-6 voor stikstofoxiden ($NO_x$) die zijn vastgesteld in 2016 liggen, ten opzichte van de emissiefactoren Euro-6 die zijn vastgesteld in 2015, voor stadswegen en buitenwegen 60%-80% hoger en voor snelwegen 0% tot 35% lager. Dit betekent dat de gemiddelde emissies $NO_x$ van personenwagens op stadswegen en buitenwegen tussen 2015 en 2020 weliswaar verder zullen dalen, maar minder snel dan eerder aangenomen.

*Emissiefactoren 2016 voor bestelwagens*
De emissiefactoren voor toekomstige Euro-6 bestelauto’s waren in 2015 nog steeds gebaseerd op oude en gunstige inschattingen. In het licht van ontwikkelingen bij Euro-5 bestelauto’s en Euro-6 personenauto’s zijn deze $NO_x$ emissiefactoren niet

meer houdbaar en zijn de waarden naar boven bijgesteld met een factor 2 tot 4. Dit betreft een voorlopige bijstelling in de richting van de uiteindelijke waarde, die pas kan worden vastgesteld als voertuigen beschikbaar komen voor metingen.

*Emissiefactoren vrachtwagens en bussen 2016*
Voor vrachtwagens en bussen zijn er in 2014 conservatieve inschattingen gemaakt op basis van de wetgeving, omdat de verwachting was dat de hele lage meetresultaten aan de eerste Euro-VI vrachtwagens op den duur hoger zouden worden. Jaar op jaar wordt deze trend gecontroleerd. De gemiddelde emissies van vrachtwagens zijn nu hoger dan bij de eerste voertuigen, en de meetresultaten naderen van onderen richting de inschattingen uit 2014 voor de emissiefactoren. Deze inschattingen zijn veelal gehandhaafd voor 2016.

*Aanpassing van rijgedrag op basis van eerder onderzoek*
Het rijgedrag dat voor het vaststellen van de emissiefactoren van 2016 wordt gebruikt, is bepaald in een groot meetprogramma. In september 2015 is hiervoor rijgedrag gemeten voor alle wegtypes en congestieklassen. Belangrijkste resultaat van dit onderzoek is dat de dynamiek op de buitenweg en op de snelweg licht is toegenomen in vergelijking met het voorheen aangenomen rijgedrag. Dit is van belang omdat de emissies van Euro-6 voertuigen zeer gevoelig lijken voor dit verschil in rijgedrag. De aanpassingen in het rijgedrag zijn meegenomen in de berekening van de nieuwe emissiefactoren.

**Inzichten voor Euro 6/VI nog niet compleet**
De inzichten op gebied van emissies van Euro-6 personen- en bestelwagens en Euro-VI vrachtwagens en bussen zijn nog niet compleet. Nog altijd verschijnen nieuwe voertuigen, met nieuwe technologieën, op de markt. Voertuigmetingen die in 2016 worden uitgevoerd, zullen naar verwachting leiden tot bijstelling van de emissiefactoren voor 2017. Zo worden Euro-6 dieselvoertuigen de komende jaren naar verwachting veelal uitgevoerd met alleen een Lean $NO_x$ Trap (LNT), een technologie die tot op heden in de praktijk tegenvallende resultaten laat zien op het gebied van met name de $NO_x$-uitstoot. Voor Euro-6 personenwagens wordt dan ook verwacht dat de $NO_x$ emissiefactoren in 2017 verder naar boven zullen moeten worden bijgesteld. Vanaf 2020 zullen de emissies van Euro-6 personenwagens die dan op de markt komen naar verwachting lager liggen, als gevolg van de invoering van een nieuwe Real Driving Emission test (RDE.) Deze verwachting voor voertuigen van 2020 en later is, op basis van de geplande Europese wetgeving, in de emissiefactoren meegenomen.

# Summary


**The importance of emission factors for air quality measurements**
A frequent monitoring of the air quality is needed to ensure a healthy living environment. In the Netherlands, the air quality is monitored through direct measurements in a program called 'Landelijk Meetnet Luchtkwaliteit'. Additionally, calculations of the air quality are performed annually. These calculations make use of air quality models, which are based on various input parameters.

The air quality in the Netherlands is to a large extend determined by road traffic. In order to make a reliable estimate of the influence of road traffic on the air quality, several factors have to be taken into account: the average fleet composition (how many vehicles drive in the Netherlands?), the distance covered (how many kilometres do these vehicles drive on average?) and the real-life emissions per vehicle (what is the average pollution per kilometre of each of these vehicles?). The average real-life emissions per vehicle are expressed in so-called emission factors.

The Dutch emission registration makes an inventory of the yearly emissions in the Netherlands, partly based on traffic emission factors. The emission factors are also used to determine the nitrogen deposition in nature. The official average emission factors are to published by the government, the underlying details are reported in same year by the National Bureau of Statistics (CBS).

The Dutch vehicle fleet is continuously evolving due to ageing of vehicles, the introduction of new models etc. Changes in the fleet composition will affect the overall emission factors. It is important that the emission factors take into account the changes in the fleet, to ensure a reliable assessment of the air quality. They are therefore evaluated annually, and adjusted if necessary, based on the most recent insights.

**Evaluation of emission factors for road traffic 2016**
This report describes the 2016 emission factors for light duty passenger cars and vans, and for heavy duty trucks and buses. Moreover, the main changes with respect to the results in 2015 are discussed. In 2015, TNO performed a study to investigate the driving behaviour of Dutch car drivers. The driving behaviour has a large influence on the emission factors, and is therefore also discussed in this report.

*Emission factors 2016 for passenger cars*
The report gives an overview of the new emission factors for 2016 for Euro-6 passenger cars. The emission factors Euro-6 for nitrogen oxides ($NO_x$) that were calculated in 2016 are, with respect to the emission factors Euro-6 that were determined in 2015, for urban roads and rural roads about 60%-80% higher, and for motorways 0%-35% lower. This entails that although the average $NO_x$ emission factors for passenger cars on urban and rural roads will further decrease between 2015 and 2020, this decrease will happen at a lower pace than previously assumed.

*Emission factors 2016 for vans*
Euro-6 vans are not yet on the market in the Netherlands. The 2015 emission factors were based on old (and favourable) estimates.

Recent measurements on Euro-5 vans and Euro-6 passenger cars imply that the old estimates for Euro-6 vans need to be increased by a factor 2-4. This is a preliminary adjustment, which will be verified when Euro-6 vans become available for measurements.

*Emission factors 2016 for trucks and buses*
Conservative estimates for the emission factors for trucks and buses were made in 2014 based on the legislative values. It was expected that the low emission results in tests of the first Euro-VI trucks would not be representative for the later models, and that the emissions would increase over time. This assumption turned out to be correct, since more recent tests show higher emissions. The results now approach from below the estimates that were made in 2014. The 2014 estimates are therefore kept in place for 2016 in almost all cases.

*Adjustment of driving behaviour*
The driving behaviour parameters that are used to calculate the 2016 results have been determined in a large measurement program. The driving behaviour was measured in September 2015, on all road types and congestion categories. This study showed that driving in rural areas and motorways is more dynamic than previously assumed. The driving dynamics have a large influence on the emission results of Euro-6 vehicles. Therefore this change in average driving behaviour is taken in account when calculating the new emission factors.

**Insights for Euro-6/VI not yet finalized**
The insights for Euro-6 passenger cars and vans and Euro-VI trucks and buses are not final, since new vehicles with new emission reduction technologies still appear on the market. The expectation is that the test results of 2016 will lead to adjustments of the emission factors in 2017. For example, most future Euro-6 diesel vehicles will have a Lean NOx Trap (LNT) installed, which showed disappointing real-life results, in particular for the NOx emissions. This implies that the NOx emission factors of Euro-6 passenger cars will most probably have to be increased in 2017. The emissions of Euro-6 passenger cars that enter the market from 2020 onwards are expected to be lower due to the new Real Driving Emission test (RDE). This expectation has been taken into account, based on the planned European legislation, for the predictions after 2020.

# Contents

# 1 Introduction

TNO performs emission measurements within the “in-use-compliance program for light duty vehicles” as a representative of the Dutch Ministry of Infrastructure and the Environment. TNO develops annually updated vehicle emission factors based on the performed emission measurements. The resulting emission factors should represent real world emission data for three various vehicle types and different driving conditions. Vehicle emission factors are used for emission inventory and air quality monitoring.

Between 1989 and 2000 many standard type approval tests were executed by means of a dynamometer, while in recent years the emphasis has shifted to the gathering of real-world emission data by various nonstandard, real-world, driving cycles. Some emissions display a large variation between the on-road emissions and the dynamometer type approval emissions. This in particular applies to the $NO_x$ emissions of diesel passenger cars, which resulted in up to six times higher emissions than the type approval limits (TNO 2013). In the current program multiple Euro-6 diesel passenger cars and Euro-VI diesel trucks were tested.

The aim of this research is to assess the real-world emission performance of Euro-6 passenger cars and Euro-VI trucks by means of new emission measurements.
The results were applied to derive emission factors for these and other vehicle categories, such as LCV’s with similar technology and emission legislation.
The on-road tests using a Smart Emissions Measurement System (SEMS) and a Portable Emissions Measurement System (PEMS) were performed in various test trips with eight Euro-6 passenger cars and seventeen EURO-VI trucks.

The Euro-6 standard for first registration is mandatory for passenger cars and small vans from September 2015. For heavier vans (1305-3500 kg) it will be enforced in September 2016. For the heavy-duty trucks the Euro-VI standard was mandatory from September 2013. The Euro standards include the limits for gaseous and particulate emissions, and are listed for all Euro-classes in Table 1 until Table 4.
In the tables the “HCe” emission factors are the exhaust total hydrocarbon emissions (volatile organic components), which are denoted with an “e” to separate them from the evaporative emissions.

Table 1: Emission limits for passenger cars

| Norm | NOx [g/km] | | HCe [g/km] | | HCe+NOx [g/km] | | CO [g/km] | | PM [mg/km] | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Petrol | Diesel | Petrol | Diesel | Petrol | Diesel | Petrol | Diesel | Petrol | Diesel |
| Euro-1 | - | - | - | - | 0.97 | 0.97 | 2.72 | 2.72 | - | 140 |
| Euro-2 | - | - | - | - | 0.5 | 0.7 | 2.20 | 1.00 | - | 80 |
| Euro-3 | 0.15 | 0.5 | 0.20 | - | - | 0.56 | 2.30 | 0.64 | - | 50 |
| Euro-4 | 0.08 | 0.25 | 0.10 | - | - | 0.30 | 1.00 | 0.50 | - | 25 |
| Euro-5 | 0.06 | 0.18 | 0.10 | - | - | 0.23 | 1.00 | 0.50 | 5 | 5 |
| Euro-6 | 0.06 | 0.08 | 0.10 | - | - | 0.17 | 1.00 | 0.45 | 4.5 | 4.5 |

Table 2: Emission limits for diesel light duty vehicles, class 1

| Emission limit | NOx [g/km] | HCe+NOx [g/km] | CO [g/km] | PM [mg/km] |
|---|---|---|---|---|
| Euro-1 | - | 0.97 | 2.72 | 140 |
| Euro-2 | - | 0.7 | 1.0 | 80 |
| Euro-3 | 0.5 | 0.56 | 0.64 | 50 |
| Euro-4 | 0.25 | 0.30 | 0.50 | 25 |
| Euro-5 | 0.180 | 0.23 | 0.500 | 5.0 |
| Euro-6 | 0.080 | 0.17 | 0.500 | 4.5 |

Table 3: Emission limits for light duty vehicles, class 3

| Emission limit | NOx [g/km] | HCe+NOx [g/km] | CO [g/km] | PM [mg/km] |
|---|---|---|---|---|
| Euro-1 | - | 1.7 | 6.9 | 250 |
| Euro-2 | - | 1.2 | 1.5 | 170 |
| Euro-3 | 0.78 | 0.86 | 0.95 | 100 |
| Euro-4 | 0.39 | 0.46 | 0.74 | 60 |
| Euro-5 | 0.28 | 0.350 | 0.740 | 5.0 |
| Euro-6 | 0.125 | 0.215 | 0.740 | 4.5 |

Table 4: Emission limits for heavy duty diesel vehicles

| Emission limit | NOx [g/kWh] | HCe [g/kWh] | CO [g/kWh] | PM [mg/kWh] | $NH_3$ [ppm] |
|---|---|---|---|---|---|
| Euro III | 5.0 | 0.66 | 2.1 | 0.1 | - |
| Euro III EEV | 2.0 | 0.25 | 1.5 | 0.02 | - |
| Euro IV | 3.5 | 0.46 | 1.5 | 0.02 | - |
| Euro IV EEV | 2.0 | 0.25 | 1.5 | 0.02 | - |
| Euro V | 2.0 | 0.46 | 1.5 | 0.02 | - |
| Euro V EEV | 2.0 | 0.25 | 1.5 | 0.02 | - |
| Euro VI | 0.4 | 0.13 | 1.5 | 0.01 | 10 |

In Chapters 2 and 3, the test results are presented for passenger cars and trucks, respectively. Using these results, emission factors for light commercial vehicles and other vehicle categories are derived in Chapter 4. For large LCV's less strict emission limits exist, the $NO_x$ emission limit is typically 60% above the emission limit of a passenger car. To calculate the emission factors the driving behaviour needs to be taken into account. The driving behaviour is characterized by a set of parameters, based on velocity and the magnitude of acceleration, which were derived for the annual update. The parameter set is described in Chapter 5.

# 2 Emissions of passenger cars measured in on-road tests

Eight diesel-fueled Euro-6 passenger cars were tested on-road, using a Smart Emissions Measurement System (SEMS) and a Portable Emissions Measurement System (PEMS) in various test trips as described in (TNO 2015a). The main results were extracted from averaging the total emissions from on-road PEMS and SEMS tests per vehicle over all the vehicles. That is, every vehicle has the same weight in the emission factor.

Chassis dynamometer tests have been the main source of emission data used to estimate real-world emissions so far. From 2014, chassis dynamometer test are not used anymore, due to the doubt of the validity of chassis dynamometer tests for real-world emissions. Dynamometer conditions are less heavy than on-road conditions. This does not explain why the $NO_x$ emission during real-world test at moderate circumstances is much higher than during chassis dynamometer tests, as observed in earlier studies (TNO 2015a). The resistance levels ("road loads") on the chassis dynamometer are lower because the official type approval data is used, to ensures a fair comparison with the type approval test results. This is expected to cause only a minor change in emissions. On the contrary, such effects are noted in $CO_2$ emissions. Lately, the gap in $CO_2$ emissions is also increasing, because type approval road load are optimised increasingly to yield low $CO_2$ emissions. Another minor deviation arises from the heavy PEMS equipment and the extra passenger in the car, which will increase the load somewhat in on-road testing.

Notwithstanding that the differences between dynamometer and on-road results is explainable to a certain degree, the difference for Euro-6 cars is too large to ignore. This does not invalidate older results for Euro-5 and earlier. For older vehicle-types, the deviation between the different tests was smaller. Only from the latest Euro-5 vehicles (2011) and later the real-world driving cycles on the chassis dynamometer gave much lower results than the on-road measurements. In particular cold-start tests showed strongly deviating results. This made it impossible to rely on chassis dynamometer measurements to determine appropriate cold start contributions to the total emissions of diesel vehicles.

The SEMS equipment provides measurements of the concentration of $CO_2$, $NO_x$ and $NH_3$, and the air flow through the exhaust. The mass flow rate of $CO_2$, $NO_x$ and $NH_3$ can be calculated using the carbon and hydrogen content of the fuel and the ambient oxygen content of air (TNO 2015b). The concentration signals ($NO_x$ and $O_2$) are calibrated for each different sensor and vehicle, and also in between measurements. The vehicle speed is registered at 1Hz using the GPS signal. The accuracy of the SEMS measurements was validated in previous projects (TNO 2014).

The PEMS system measures CO, $CO_2$, HC, $NH_3$, NO, $NO_2$ and $NO_x$. It provides more accurate measurements of the mass flow than the SEMS system, but is also more expensive and more difficult to install. Not all vehicles could be tested with PEMS. The number of measurements per vehicle and measurement system are listed in Table 5.

Table 5 : List of performed measurements per vehicle

| Vehicle | On-road PEMS | On-road SEMS |
|---|---|---|
| 1 | 16 trips, 1436 km | 21 trips, 1123 km |
| 2 | 13 trips, 817 km | - |
| 3 | 9 trips, 635 km | - |
| 4 | 8 trips, 673 km | - |
| 5 | - | 56 trips, 4073 km |
| 6 | 10 trips, 586 km | - |
| 7 | 5 trips, 322 km | 16 trips, 1688 km |
| 8 | - | 16 trips, 1844 km |

The on-road data was recorded for a variety of routes. Every vehicle performed a reference trip on a fixed trajectory and a number of random trips with different driving styles (sportive, eco-driving) and different road types (city roads, motorways and rural roads). The data was recorded at a frequency of 1Hz. Subsequently the data was analysed and modelled as a function of velocity and acceleration, such that the resulting emission factors for a specific vehicle (Ligterink, De Lange 2009) are driving scheme independent. The emission measurements were reweighted for different road and congestion types, as defined in Table 15 of Appendix A.
The emission model VERSIT+ averages the emission data per velocity and acceleration, which is combined with the velocities and accelerations as they occur for different road types and congestion levels. This yields the emission factor for the different traffic situations.

Table 6: The 2015 Euro-6 emission factors for diesel passenger cars (LPADEUA6), per road type

| Road type | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.079 | 257 | 0.054 | 1 | 119 | 379 |
| WM1 | 0.046 | 152 | 0.032 | 1 | 71 | 237 |
| WF1 | 0.060 | 144 | 0.038 | 1 | 69 | 252 |
| WT1 | 0.046 | 152 | 0.032 | 1 | 71 | 237 |
| WT2 | 0.057 | 87 | 0.030 | 1 | 53 | 202 |
| W80MSH (W83) | 0.086 | 111 | 0.033 | 1 | 76 | 260 |
| WS3 | 0.073 | 228 | 0.042 | 1 | 132 | 377 |
| WT3 | 0.104 | 139 | 0.035 | 1 | 128 | 420 |
| W100MSH (W03) | 0.097 | 130 | 0.029 | 1 | 122 | 387 |
| W100ZSH (W13) | 0.100 | 131 | 0.031 | 1 | 123 | 394 |
| W120ZSH (W23) | 0.110 | 140 | 0.036 | 1 | 131 | 437 |
| W130 (W33) | 0.116 | 144 | 0.038 | 1 | 138 | 468 |

Table 7: New 2016 on-road Euro-6 emission factors for diesel passenger cars (LPADEUA6) per road type. Along with the average value over all vehicles a bandwidth is quoted, which is the average after excluding the vehicle with either the minimum or the maximum emission factor.

| | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | NH3 [mg/km] | NO2 [mg/km] | NOx [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | **0.75** | **317** | **0.0255** | **3.65** | **288** | **679** |
| | 0.428 - 0.842 | 304 - 336 | 0.0215 - 0.0294 | 2.63 - 4.78 | 213 - 318 | 638 - 741 |
| WM1 | **0.565** | **246** | **0.0188** | **2.83** | **225** | **571** |
| | 0.288 - 0.641 | 233 - 261 | 0.016 - 0.0219 | 2.08 - 3.7 | 169 - 249 | 538 - 625 |
| WF1 | **0.356** | **190** | **0.0133** | **2.3** | **176** | **454** |
| | 0.194 - 0.4 | 180 - 200 | 0.0106 - 0.0155 | 1.68 - 3.01 | 136 - 196 | 427 - 498 |
| WT1 | **0.487** | **231** | **0.0171** | **2.7** | **212** | **534** |
| | 0.264 - 0.549 | 219 - 244 | 0.0141 - 0.0199 | 1.98 - 3.54 | 161 - 235 | 504 - 585 |
| WT2 | **0.255** | **172** | **0.0118** | **2.16** | **157** | **397** |
| | 0.163 - 0.281 | 163 - 181 | 0.00792 - 0.0139 | 1.68 - 2.82 | 125 - 174 | 370 - 436 |
| W80MSH | **0.152** | **129** | **0.00822** | **1.68** | **122** | **310** |
| | 0.113 - 0.163 | 123 - 135 | 0.00534 - 0.00972 | 1.3 - 2.21 | 98.2 - 135 | 289 - 341 |
| WS3 | **0.644** | **257** | **0.0205** | **2.94** | **233** | **594** |
| | 0.315 - 0.734 | 243 - 272 | 0.0177 - 0.0239 | 2.19 - 3.85 | 174 - 258 | 559 - 648 |
| WT3 | **0.166** | **174** | **0.0131** | **1.86** | **165** | **404** |
| | 0.143 - 0.178 | 161 - 182 | 0.00484 - 0.0158 | 1.01 - 2.41 | 150 - 185 | 342 - 447 |
| W100MSH | **0.142** | **140** | **0.0109** | **1.76** | **111** | **253** |
| | 0.118 - 0.152 | 131 - 147 | 0.00443 - 0.013 | 1 - 2.29 | 94.5 - 123 | 224 - 279 |
| W100ZSH | **0.146** | **150** | **0.0116** | **1.77** | **127** | **294** |
| | 0.124 - 0.156 | 140 - 158 | 0.00443 - 0.0139 | 0.968 - 2.31 | 111 - 141 | 255 - 325 |
| W120ZSH | **0.153** | **168** | **0.0128** | **1.79** | **156** | **377** |
| | 0.136 - 0.163 | 155 - 176 | 0.00441 - 0.0156 | 0.918 - 2.33 | 143 - 175 | 317 - 418 |

The total emission factors were determined by averaging the emission factors of all the tested vehicles.

Table 7 lists the current results, where the bandwidth was calculated by taking the average after removing the vehicle with either the highest or the lowest value. The number of vehicles are limited, but generally the variation in emission among the vehicles is the largest source of uncertainty. The removal of the worst and the best performing vehicle are a rough proxy of the overall uncertainty. For reference, Table 6 lists the Euro-6 diesel passenger car emission factors from the previous update in 2015, which were estimated from the Euro-5 measurements, adjusted to the Euro-6 regulations. There are some differences between the emission factors dating from 2015 and the current values. To some extend the differences can attributed to the emission measurements instead of the theoretical derivation and the implementation of the new driving behaviour parameters. The driving behaviour is applied to calculate the emissions per road type, as described in Chapter 5.

- CO values are higher for all road types, but the most striking difference occurs at urban driving, where they can be a factor 10 higher than estimated before. This can be explained by after treatment technologies such as an LNT, which increase CO emissions.
- $CO_2$ values are slightly higher for all road types, again mostly for urban road types.
- HCe (i.e. HC with “e” for exhaust, to distinguish it from evaporative HC emissions), values are a factor 2 to 3 lower than initially estimated high on the basis of mainly LNT technology prior to 2014, probably due to the recent shift from LNT technology to SCR technology in the last year.
- $NH_3$ values were not included before, but are now also measured and reported for emission inventories and nitrogen deposition.
- $NO_x$ values are higher for urban and rural driving (see also Figure 2.1). The old estimated $NO_x$ was based on the assumption that the values would converge to the regulation limits, but this turned out not to be the case, mainly for urban and congested driving.
- $NO_2$ values show a similar pattern as $NO_x$ values.

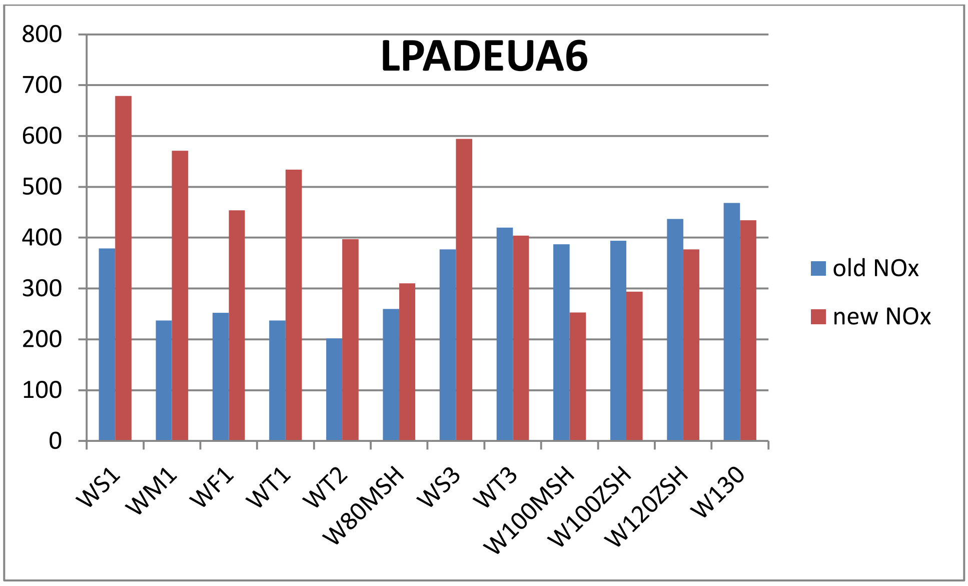


Figure 2.1: Comparison between NOx emission factors for Euro-6 passenger cars in the 2015 list (old) and the 2016 update (new)

The new emission factors are also shown in Figure 2.2 and Figure 2.3. Along with the average value over all vehicles a bandwidth is shown, which is the average after excluding the vehicle with either the minimum or the maximum emission factor. This gives an idea of the uncertainty despite the limited number of measurements. Although it differs per emission compound, the uncertainty is in general less than 10%. For other components than $NO_x$ and $CO_2$ the variation with technology is much larger, an therewith the uncertainty for these emission components. Figure 2.4 and Figure 2.5 illustrates the spread of the results for the whole sample. A common trend can be observed for the different vehicles: Above 100 km/h, the $NO_x$ emission strongly increases, and congested (WS3) and urban driving cause high $NO_x$ emissions. Consequently the increase of congestion by a few percent will increase the emissions by a few percent too. If a location of high congestion spatially shifts it may have a large consequence for these location bound emission and the resulting air-quality. The $NO_x$ values for all road types are much higher than the emission limit (80 mg/km) for diesel passenger cars.

Vehicle 2 (vehicle J2 in TNO 2015a) does not follow the common trend, and has higher emissions on the motorway than in the city.

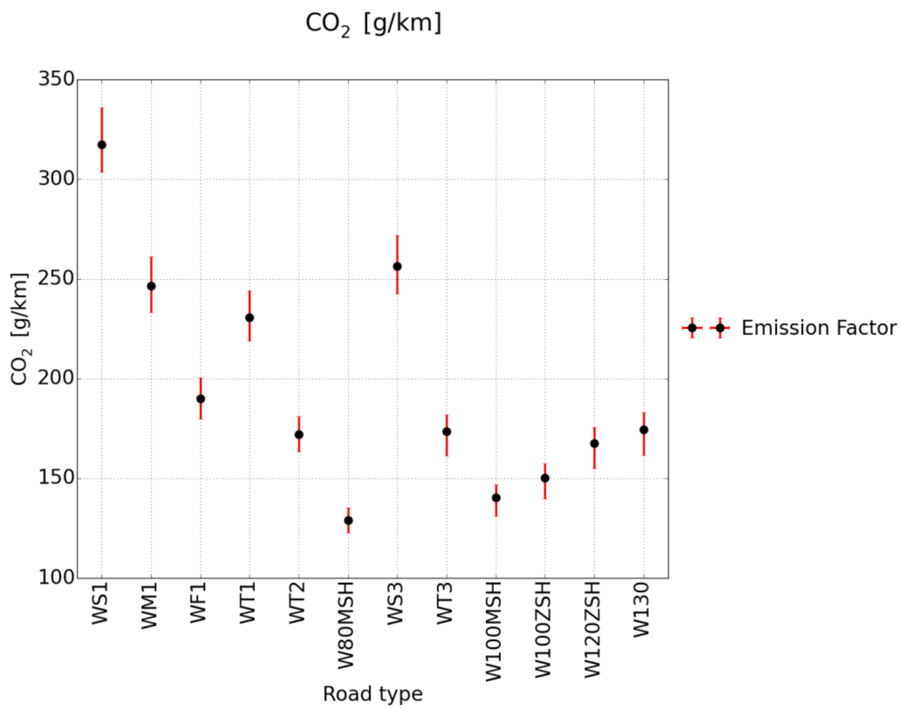


Figure 2.2: $CO_2$ emissions: averaged over all passenger cars. Along with the average value over all vehicles a bandwidth is shown, which is the average after excluding the vehicle with either the minimum or the maximum emission factor.

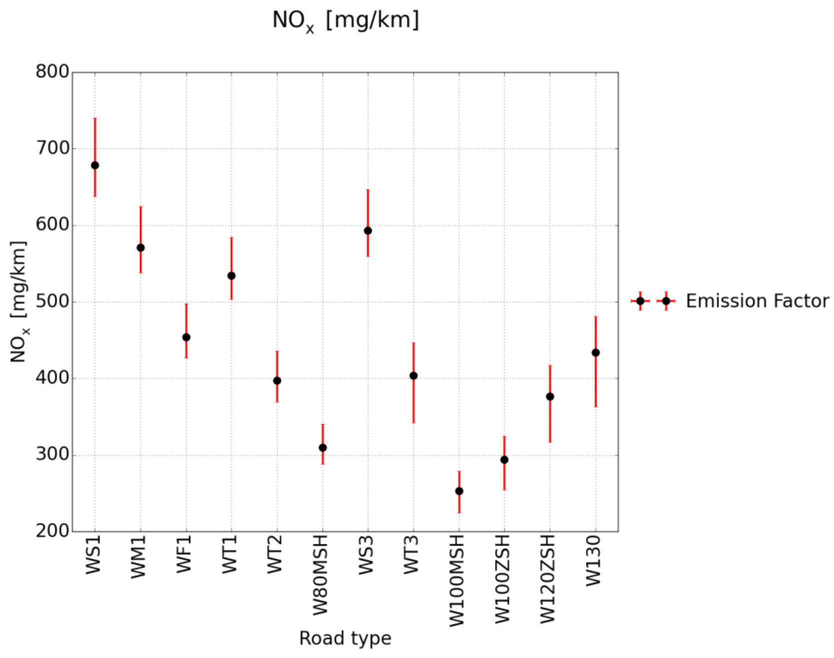


Figure 2.3: $NO_x$ emissions: minimum and maximum value and averaged over all passenger cars. Along with the average value over all vehicles a bandwidth is shown, which is the average after excluding the vehicle with either the minimum or the maximum emission factor.

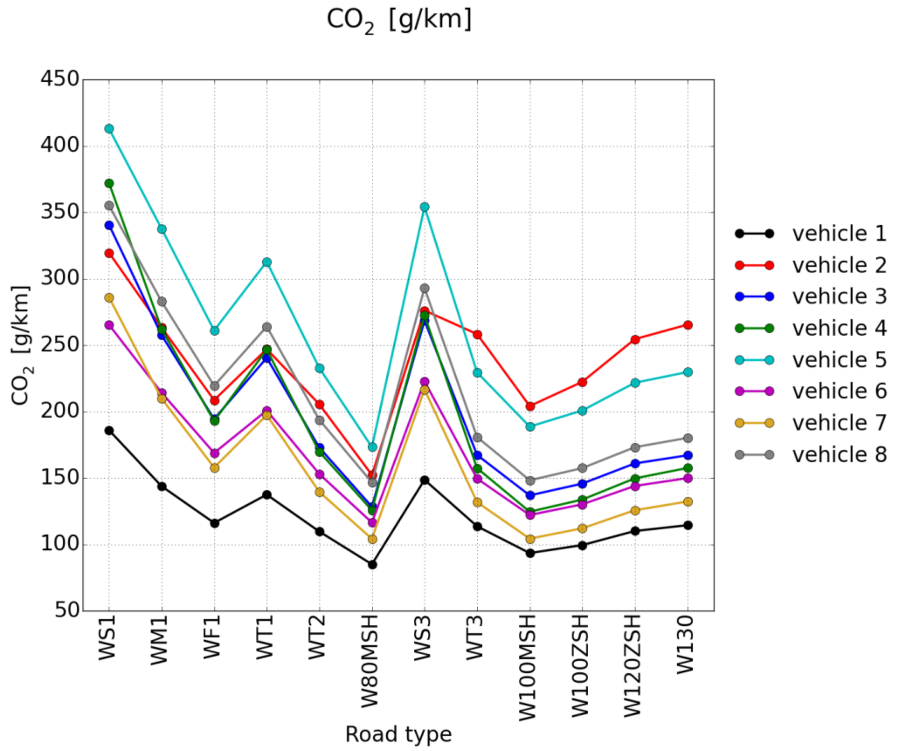


Figure 2.4: $CO_2$ emission factors for eight Euro-6 passenger cars. The lines connecting the points are added for clarity.

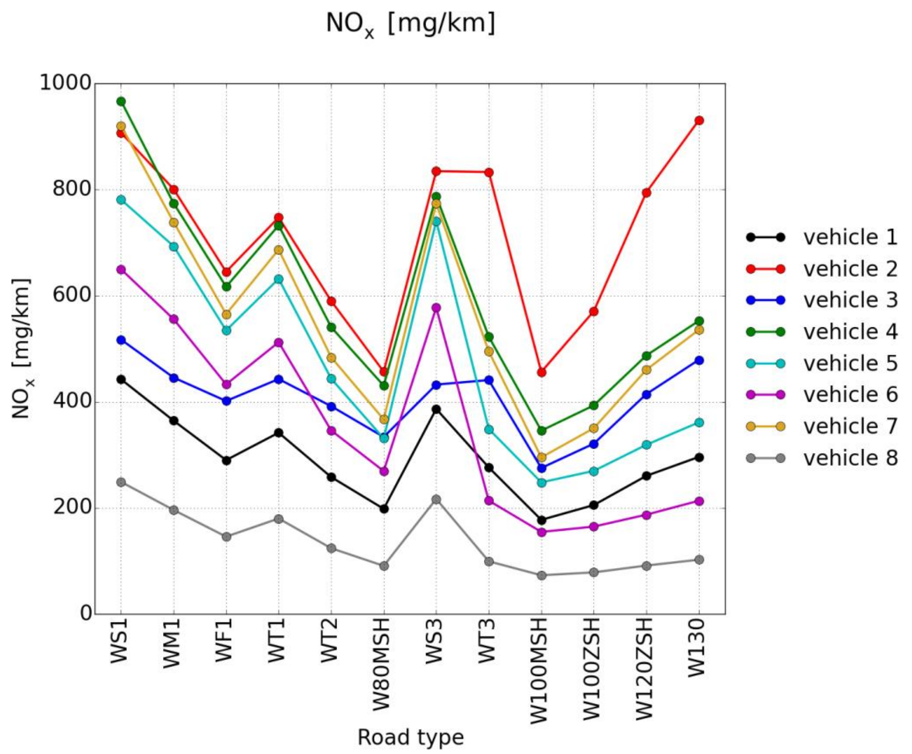


Figure 2.5: $NO_x$ emission factors for eight Euro-6 passenger cars. The lines connecting the points are added for clarity.

The $NO_x$ versus $CO_2$ emission factors for a general urban, rural and motorway road are shown in Figure 2.6. In general, the $NO_x$ emission is proportional to the $CO_2$ emission. The data pairs ($NO_x$, $CO_2$) show a large scatter. The relative position of average, or normal, urban (WT1), average rural (WT2) and average motorway (WT3) shows the same relative behaviour for each vehicle, except vehicle 2 with the highest emission for urban driving. This is supported by the figures that show the $CO_2$ and $NO_x$ emissions for all the different road types (Figure 2.4 and Figure 2.5).

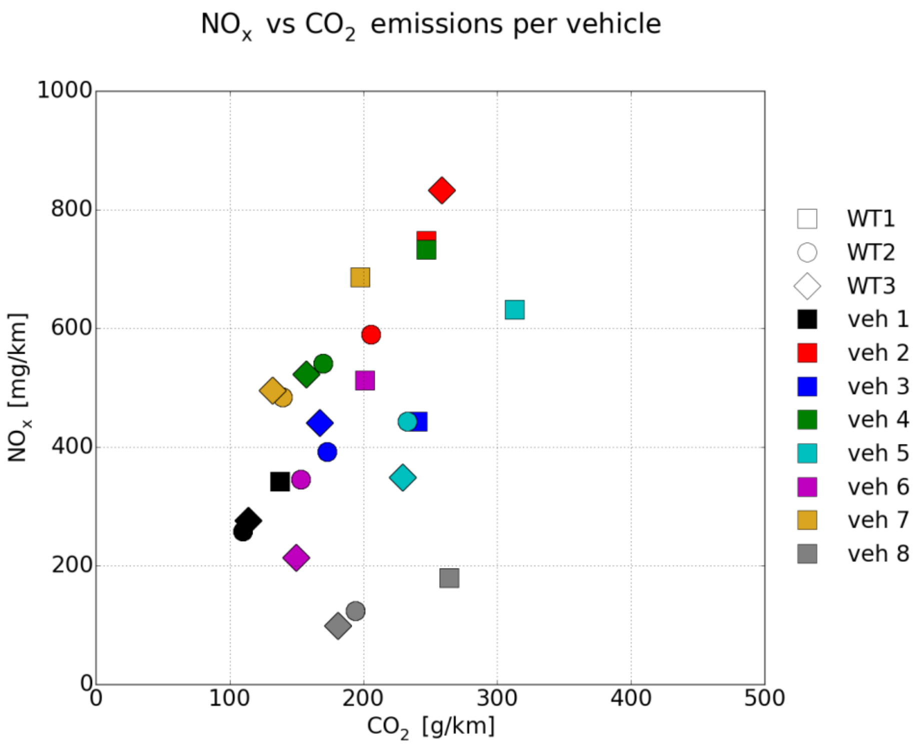


Figure 2.6: $NO_x$ versus $CO_2$ emissions per vehicle, for three different road types.

# 3 Emissions of heavy-duty vehicles measured in on-road tests

For Euro-V on-road testing has led to a substantial change in emission factors in 2009. Since then, all heavy-duty vehicles are tested on-road, with PEMS equipment. On-road tests with the Portable Emissions Measurement System (PEMS) were performed in various test trips with 17 diesel-fuelled Euro-VI trucks.[1]

In the past already very low $NO_x$ emissions were measured for Euro-VI trucks. These were mainly new, large long-haulage trucks. It was not expected that the high level of performance would hold over in time, and achieved for smaller trucks and buses. Therefore, the Euro-VI emission factors for the future years were set equal to the emission limit. The new measurements show that the emissions of modern Euro-VI trucks are still below the emission limit, but substantially higher than for the first Euro-VI trucks. Besides that, the measurements of city-busses reveal an emission risks for inner-city usage. A few buses have emissions very close and sometimes above the limit. The goal of the current investigation is to show that the assumption for heavy-duty Euro-VI vehicles is still tenable. Only in the case that the emission factors are higher than previously established, the emission factors will be updated. This is mainly the case of HCe emissions, where alternative emission reduction technologies cause an increase in HCe emissions. Occasionally an increase in CO is also visible. The precise cause of this increase in HCe emissions was not investigated. But generally, new $NO_x$ emission reduction technologies seem to be associated with high HCe emissions.

For calculation of road type specific emission factors from on-road-test measurements with PEMS, the TNO vehicle emission model VERSIT+ was used (see Ligterink & Lange, 2009). Roughly, this works in two steps.

Firstly, a VERSIT+ specific vehicle group model is derived from the performed on-road-test measurements. In this case the model was derives from the PEMS measurements only, for the group of Euro-VI diesel trucks. Secondly, the VERSIT+ Euro-VI diesel truck model is used to calculate road-type specific emission factors, taking into account the seven ‘standard’ classes of Euro-VI trucks, which differ in total mass and rated power.

For Euro-VI diesel trucks the seven VERSIT+ standard classes are as indicated in Table 8.

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[1] The Smart Emissions Measurement System (SEMS) measurements were not included, since not all of those include sufficient information to determine emission factors with the current evaluation method for heavy duty vehicles.

Table 8: The seven VERSIT+ standard classes for Euro-VI diesel trucks

| VERSIT+ Standard Class | Description | Mass (tonne) | Power (kW) |
|---|---|---|---|
| **MVADEUR6LCH** | Rigid Truck Light | 5,210 | 126 |
| **MVADEUR6ZWA** | Rigid Truck Heavy | 11,820 | 239 |
| **ZVADEUR6** | Heavy Rigid Truck | 19,500 | 302 |
| **ZVADEUR6ANHLCH** | Heavy Rigid Truck with Trailer Light | 23,220 | 239 |
| **ZVADEUR6ANHZWA** | Heavy Rigid Truck with Trailer Heavy | 35,940 | 302 |
| **ZTRDEUR6LCH** | Tractor Semi-Trailer Light | 19,000 | 300 |
| **ZTRDEUR6ZWA** | Tractor Semi-Trailer Heavy | 42,750 | 300 |

For these seven Euro-VI vehicle classes, road type specific emission factors were calculated with VERSIT+ for the emissions of CO, $CO_2$, HC, $NO_2$ and $NO_x$ for the road types WT1 (urban), WT2 (rural), WT3 (motorway), WS1 (urban, congested), WM1 (= WT1 or urban normal), WF1 (urban, free flow) and WS3 (motorway, congested). A comprehensive overview of all road types used in this report in presented in Table 15 in Appendix A.

The resulting emission factors are presented in the Appendix where they are listed in seven sets of three tables.

The emission factors are graphically presented as a function of road type per Euro-VI VERSIT+ standard class in Figure 3.1 to Figure 3.5 on page 20. As one may observe, all emission factors decrease when going from urban (WT1) via rural (WT2) to motorway (WT3). This reflects the decrease in vehicle driving dynamics as well as the increase in motor efficiency for these road types. Looking at the urban road type group for decreasing traffic intensity levels, i.e. congested (WS1), normal (WM1) and free flow (WF1), a similar decrease for all emission factors is observed.

For inter-comparison the current 2016 and the 2015 emission factors for ZVADEUR6, as well as the relative differences between the 2015 and 2016 emission factors, are listed in Table 9 to Table 11. Note that the 2015 emission factors are conservative estimates for Euro-VI vehicles as established in 2014. These vehicles have been introduced on the market recently. Since the vehicles tested for this update are very new models, it is expected that they suggest a very favourable image of the future Euro-VI fleet. Therefore, only the emission factors measured higher than the conservative estimates from 2014, as used in 2015 as well, will actually be updated.

The differences between the 2016 and 2015 CO and $CO_2$ emission factors are rather small or even negligible, while the differences for $NO_2$ and $NO_x$ emission factors are substantially lower, by almost 50%, but higher than the first measurements used in the update of the emission factors since 2014. Hence, these numbers will not be updated. Most striking however is the large difference, about factor of 5 to 10, between the 2016 HCe and the 2015 HCe emission factors.

Going through all the tables in the Appendix a similar picture emerges.

Table 9: Emission factors, as calculated for 2016 update, for ZVADEUR6

| ZVADEUR6, Heavy Rigid Truck, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.911 | 1186.272 | 0.151 | 0.157 | 0.476 |
| WT2 | 1.066 | 834.857 | 0.093 | 0.127 | 0.303 |
| WT3 | 0.765 | 687.871 | 0.082 | 0.110 | 0.177 |
| WS1 | 3.058 | 1898.035 | 0.242 | 0.251 | 0.761 |
| WM1 | 1.911 | 1186.272 | 0.151 | 0.157 | 0.476 |
| WF1 | 1.357 | 842.253 | 0.107 | 0.111 | 0.338 |
| WS3 | 1.911 | 1186.272 | 0.151 | 0.157 | 0.476 |

Table 10: Current, i.e. as published in 2015, emission factors for ZVADEUR6

| ZVADEUR6, Heavy Rigid Truck, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.911 | 1208.150 | 0.019 | 0.299 | 0.855 |
| WT2 | 0.967 | 797.987 | 0.011 | 0.198 | 0.565 |
| WT3 | 0.653 | 655.666 | 0.007 | 0.162 | 0.464 |
| WS1 | 3.057 | 1933.050 | 0.031 | 0.479 | 1.368 |
| WM1 | 1.911 | 1208.150 | 0.019 | 0.299 | 0.855 |
| WF1 | 1.357 | 857.790 | 0.014 | 0.212 | 0.607 |
| WS3 | 1.911 | 1208.150 | 0.019 | 0.299 | 0.855 |

Table 11: Relative differences between 2015 and 2016 emission factors

| ZVADEUR6, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| Road Type | CO ΔEF | CO2 ΔEF | HCe ΔEF | NO2 ΔEF | NOx ΔEF |
| | % | % | % | % | % |
| WT1 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |
| WT2 | 10.25 | 4.62 | 723.91 | -35.78 | -46.32 |
| WT3 | 17.23 | 4.91 | 1012.01 | -32.21 | -61.95 |
| WS1 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |
| WM1 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |
| WF1 | 0.03 | -1.81 | 690.29 | -47.66 | -44.38 |
| WS3 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |

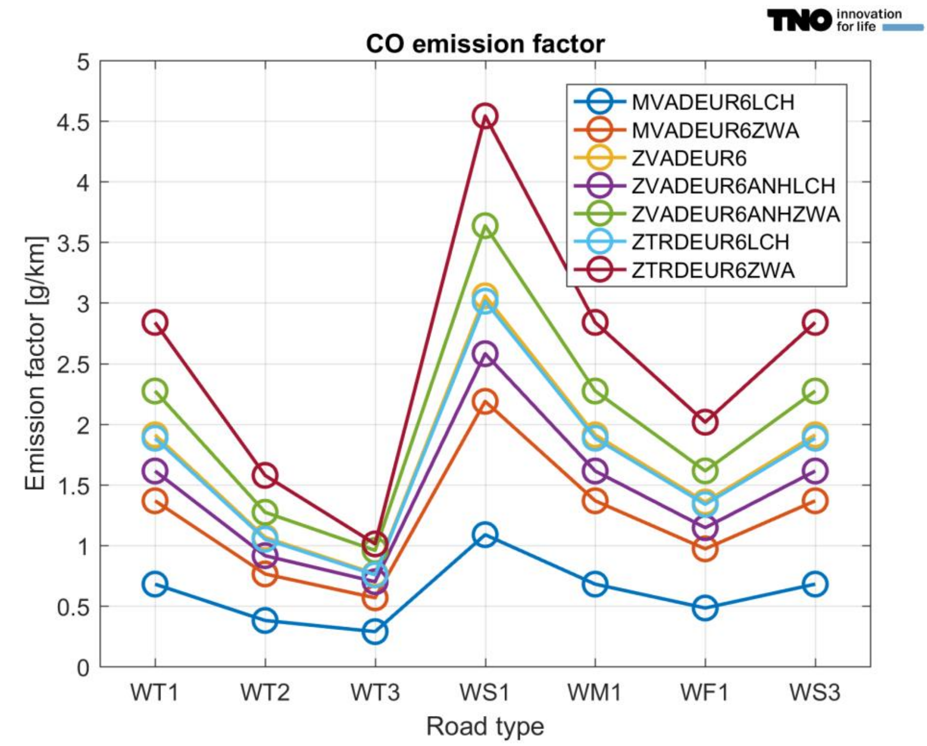


Figure 3.1: CO emission factor as function of road type per Euro-VI VERSIT+ standard class. The lines connecting the points are added for clarity.

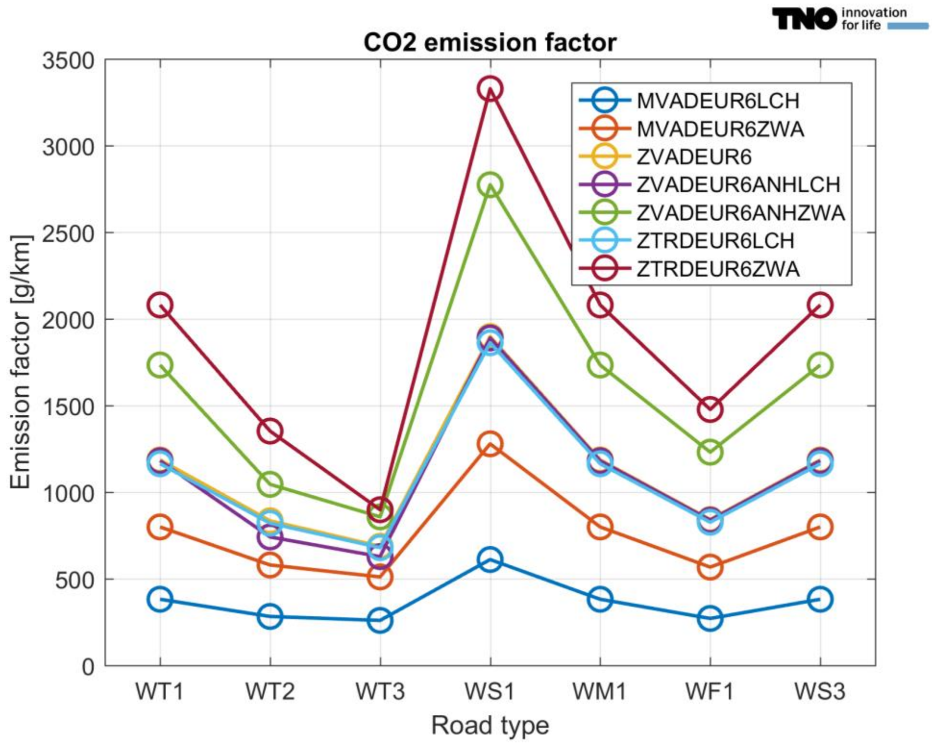


Figure 3.2: $CO_2$ emission factor as function of road type per Euro-VI VERSIT+ standard class.

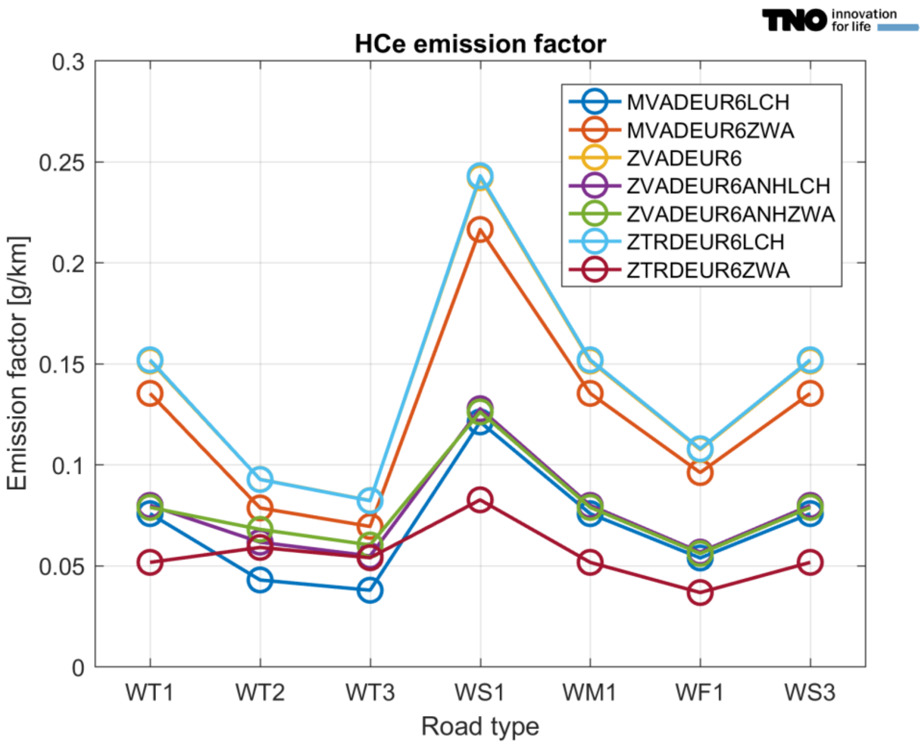


Figure 3.3: HCe emission factor as function of road type per Euro-VI VERSIT+ standard class.

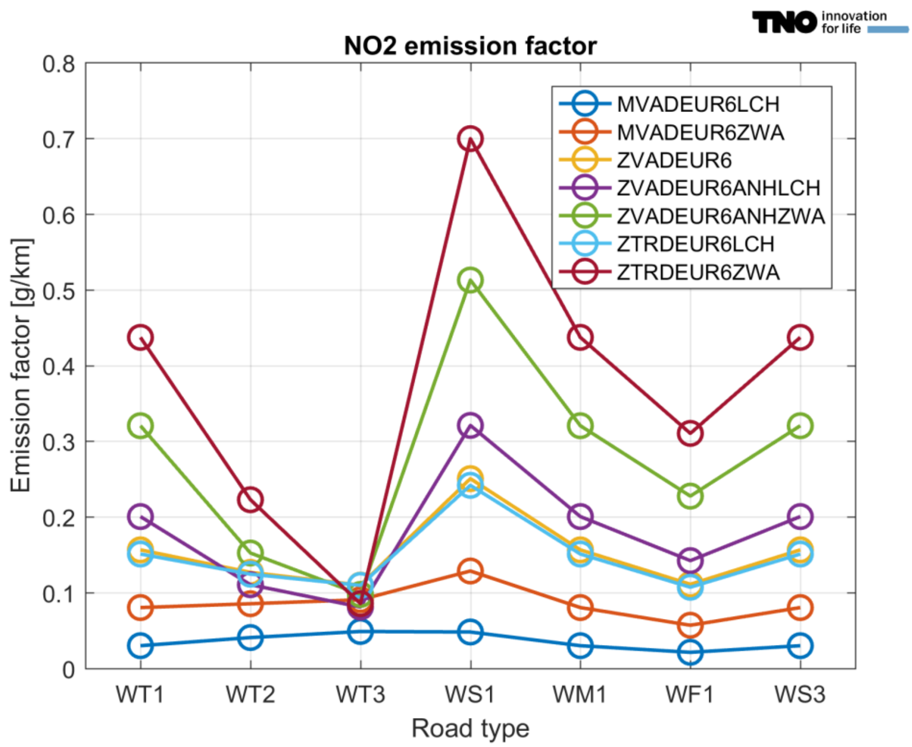


Figure 3.4: $NO_2$ emission factor as function of road type per Euro-VI VERSIT+ standard class.

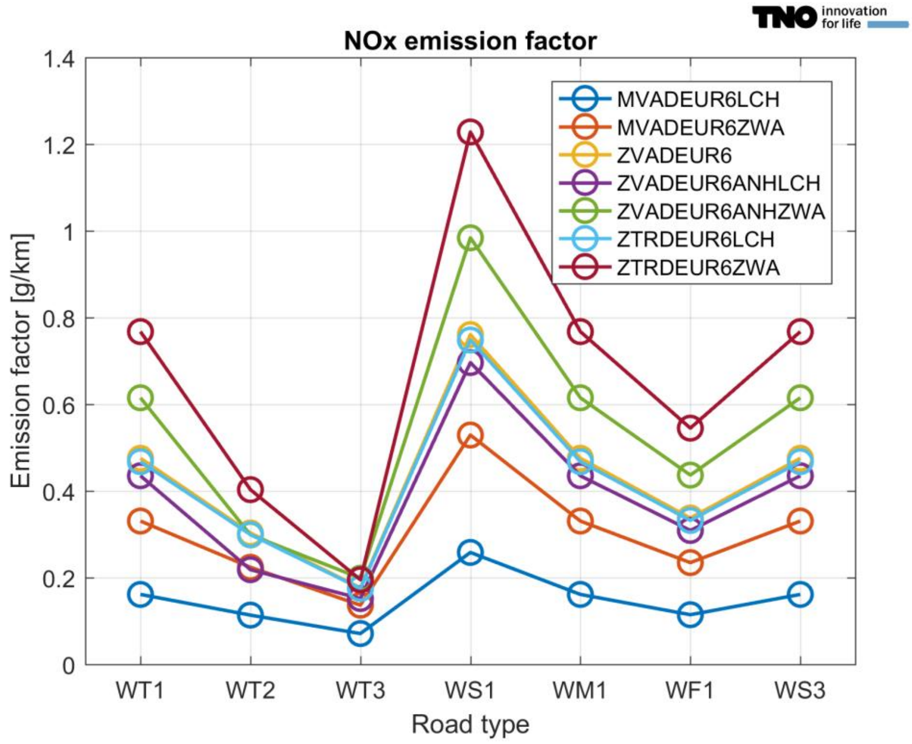


Figure 3.5: $NO_x$ emission factor as function of road type per Euro-VI VERSIT+ standard class.

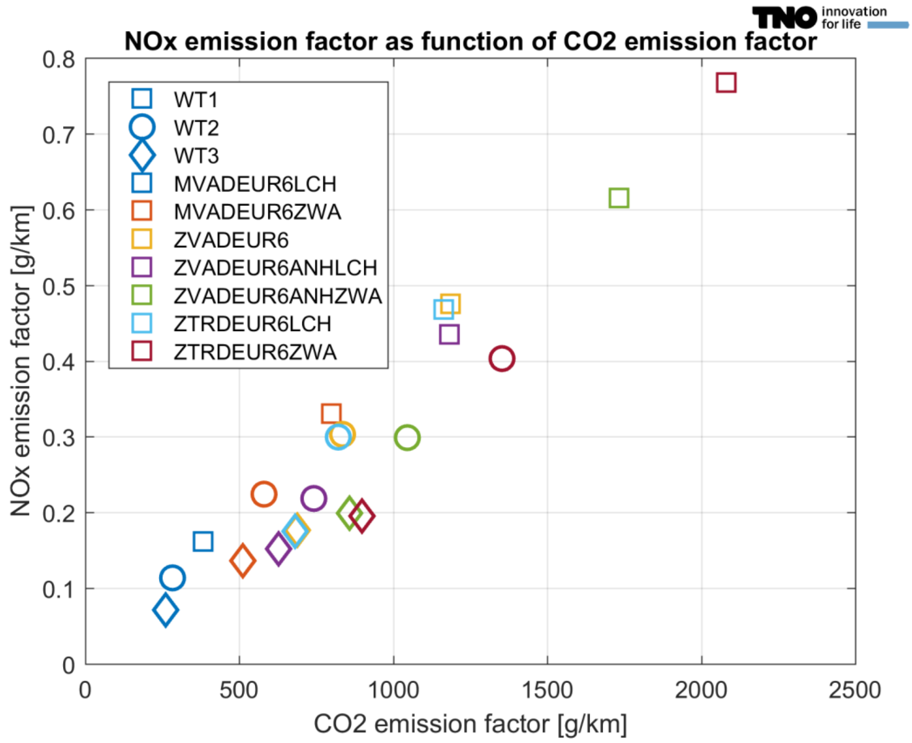


Figure 3.6: NOx emission factor as function of $CO_2$ emission factor for road types WT1 to WT3 and all Euro-VI diesel VERSIT+ standard classes.

# 4 Emissions of light commercial vehicles

The test program did not include any Euro-6 light commercial vehicles (LCV's), as they were not yet available. However, a recent report was made on the results of Euro-5 light commercial vehicles, which showed that the emissions for Euro-5 LCV's are much higher than previously assumed (TNO 2015b). The 2015 Euro-6 emission factors for LCVs are shown in Table12. Since the Euro-6 emission legislation only applies for LCV's from September 2016, for the heavy LCV's (Class III), few such vehicles are available. Hence no update has been applied recently for the emission factors of Euro-6 LCV's. However, it is expected that the current values are too low for a proper prognoses, and an theoretical update prior to any emission measurement is warranted.

To estimate the Euro-6 light commercial vehicles (LCV) $NO_x$ and $NO_2$ emission factors without measurements, it is assumed that the innovations in Euro-6 vehicles with respect to the Euro-5 generation have a similar effect on the emissions of LCV as on those of passenger cars. Within this assumption the ratio between the Euro-6 and Euro-5 LCV emission factors is equal to the ratio between the Euro-5 and Euro-6 emission factors in passenger cars. In this way the Euro-6 LCV emission factors are extrapolated form the Euro-5 LCV measurements. For $NH_3$, no previous emission factors are available, so the Euro-6 passenger car value is adopted for LCV's. For CO and HCe, there are no measurement values of Euro-5 LCV's available. Therefore the ratio of class III over class I LCV's from the European emission standards is used to scale from Euro-6 passenger cars to Euro-6 LCV's.

The results for Euro-6 LCV's are shown in Table 13. As expected, the extrapolation causes to increase all emission factors (compared to the previous emission factors in Table 12). Especially the $NO_x$ values are higher: up to a factor 5 for the road types with highest emissions.

A similar extrapolation of measurement results from one category to another can be applied to other vehicle categories. The way in which this is done for the current update is summarised in Table 14. Detailed results are shown in the Appendix.
For all the categories for which no, or limited data, is available, similar vehicle technologies combined with the relative stringency of the emission legislation are used to estimate the emission factors. This is for example the case for vehicles which are not yet on the road, but needed for prognoses to 2020 and beyond.

Table 12: The 2015 Euro-6 emission factors, for diesel light commercial vehicles (LBADEUA6ZWA) per road type

| | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.117 | 257 | 0.068 | - | 185 | 379 |
| WM1 | 0.068 | 152 | 0.041 | - | 112 | 237 |
| WF1 | 0.089 | 144 | 0.048 | - | 108 | 252 |
| WT1 | 0.068 | 152 | 0.041 | - | 112 | 237 |
| WT2 | 0.085 | 87 | 0.038 | - | 82 | 202 |
| W80MSH | 0.127 | 111 | 0.042 | - | 119 | 260 |
| WS3 | 0.108 | 228 | 0.053 | - | 207 | 377 |
| WT3 | 0.157 | 141 | 0.044 | - | 200 | 420 |
| W100MSH | 0.143 | 130 | 0.036 | - | 191 | 387 |
| W100ZSH | 0.148 | 131 | 0.039 | - | 192 | 394 |
| W120ZSH | 0.162 | 140 | 0.045 | - | 205 | 437 |
| W130 | 0.172 | 144 | 0.049 | - | 216 | 468 |

Table 13 New 2016 Euro-6 emission factors for diesel light commercial vehicles (LBADEUA6ZWA) per road type

| LBADEUA6ZWA | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 1.12 | 347 | 0.0321 | 3.65 | 675 | 1.65E+03 |
| WM1 | 0.848 | 256 | 0.0237 | 2.83 | 538 | 1.31E+03 |
| WF1 | 0.535 | 205 | 0.0167 | 2.3 | 427 | 1.04E+03 |
| WT1 | 0.731 | 247 | 0.0215 | 2.7 | 509 | 1.24E+03 |
| WT2 | 0.383 | 205 | 0.0148 | 2.16 | 393 | 958 |
| W80MSH | 0.227 | 158 | 0.0104 | 1.68 | 300 | 731 |
| WS3 | 0.966 | 260 | 0.0258 | 2.94 | 546 | 1.33E+03 |
| WT3 | 0.25 | 247 | 0.0165 | 1.86 | 438 | 1.07E+03 |
| W100MSH | 0.213 | 208 | 0.0137 | 1.76 | 327 | 797 |
| W100ZSH | 0.219 | 221 | 0.0146 | 1.77 | 361 | 881 |
| W120ZSH | 0.229 | 244 | 0.0161 | 1.79 | 423 | 1.03E+03 |
| W130 | 0.236 | 249 | 0.0165 | 1.79 | 452 | 1.10E+03 |

Table 14: Derivation of emission factors from other vehicle categories

| | CO | $CO_2$ | $NH_3$ | $NO_2$ | NOx | HCe |
|---|---|---|---|---|---|---|
| LBADEUR5ZWA | 1.5 * LPADEUR5 CO | from archived u-values | - | 0.3 * LBADEUR5ZWA NOx | from archived u-values | 1.26*LPADEUR5 HCe |
| LBADEUA6ZWA | 1.48*LPADEUA6 CO | LBADEUR5ZWA CO2 | LPADEUA6 NH3 | 0.41* LBADEUA6ZWA NOx | LBADEUR5ZWA * LPADEUA6 / LPADEUR5 | 1.26*LPADEUA6 HCe |
| LPADEUR5 | measured | measured | - | measured | measured | measured |
| LPADEUA6 | measured | measured | measured | measured | measured | measured |
| LBADEUR5LCH | LPADEUR5 | LPADEUR5 | - | LPADEUR5 | LPADEUR5 | LPADEUR5 |
| LBADEUA6LCH | LPADEUA6 | LPADEUA6 | - | LPADEUA6 | LPADEUA6 | LPADEUA6 |
| LPADEUC6 | LPADEUA6 | LPADEUA6 | LPADEUA6 | 0.41* LPADEUC6 NOx | 1.5*80* LPADEUA6 RWCO2/95 | LPADEUA6 |
| LBADEUC6LCH | LBADEUA6LCH | LBADEUA6LCH | LBADEUA6LCH | 0.41* LBADEUC6LCH NOx | 1.5*80* LBADEUA6LCH RWCO2 / 95 | LPADEUA6 |
| LBADEUC6ZWA | LBADEUA6ZWA | LBADEUA6ZWA | LBADEUA6ZWA | 0.41* LBADEUC6ZWA NOx | 1.5*125* LBADEUA6ZWA RWCO2 / 147 | LBADEUA6ZWA |

# 5 New driving behaviour parameters

To calculate emission factors, the TNO vehicle emission model VERSIT+ is provided with an emissions per speed-acceleration hot map. However, another input is needed, namely driving parameters describing average driving behaviour. The driving behaviour is defined as the relative time spent in each 2-dimensional interval or bin of the speed-acceleration hot map. To determine what the distribution of these parameters is for different road types, the average driving behaviour on such roads needs to be measured. Since the driving parameters were derived from separate test programs, some dating back more than a decade ago, they might be outdated. Therefore, TNO set up a dedicated measurement programme to derive the current driving parameters for passenger cars (Ligterink 2016).

In order to do this, 1Hz velocity data was collected by a test car during several weeks, through a car-following method. The test car randomly followed other cars for a certain time, thereby covering all different road types in the Netherlands. Data was collected throughout the day and night, on all week days and outside holidays to get a representative sample of congestion levels.

Every data point in the 1Hz velocity-acceleration dataset was assigned to a certain road type, in accordance with the local maximum speed limit and the actual speed of the vehicle. Then the data was divided into the three main categories WT1, WT2 and WT3, which were subsequently divided into all the different road type definitions from Table 15. The same binning procedure that determined the VERSIT+ hot map area for a given velocity and acceleration (Ligterink, de Lange 2009) was used to count the time spent in a certain hot map for each road type. Finally the driving behaviour parameter values were normalised to the number of seconds per kilometre driven at a certain speed and acceleration.

Figure 5.1 shows how the time is divided between the three main road types: urban, rural and motorway. Rural driving for example mainly occurs at provincial roads with a speed limit of 80 km/h, hence the narrow peak at 80 km/h. For motorway driving there is no such clear peak in speed, and therefore one first needs to split this up to road types with a more specific speed definition: roads with speed limits of 100, 120 and 130 km/h. The result of this distinction is shown in Figure 5.2. It is remarkable that for the 120 km/h roads, there is still a large contribution at 100 km/h. The most occurring velocity at 130 km/h roads is actually the same as that at 120 km/h roads, although the average velocity is higher. The contributions at low velocities (below 50 km/h) are all considered to be due to congestion.

The new definition of the driving parameters results in a higher average velocity, for all road types. Furthermore, the dynamics (acceleration and deceleration) on motorways is larger than was assumed before. On the motorway, part of this dynamics is associated with situations of moderate congestion. Higher dynamics and higher velocities in general increase the $NO_x$ emissions. Mainly for Euro-6 vehicles, which show more variation in emissions for different road types than Euro-5 due to certain optimisations of the emission regulation techniques, this means that the $NO_x$ emission factors will increase.

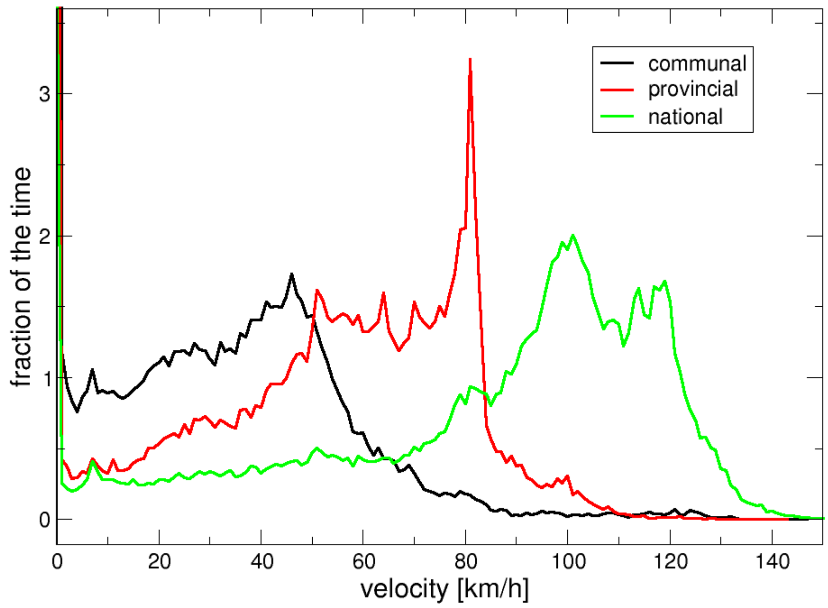


Figure 5.1: Fraction of time in percent spent at a certain velocity, for the three main road types (WT1 (urban), WT2 (rural) and WT3 (motorway))

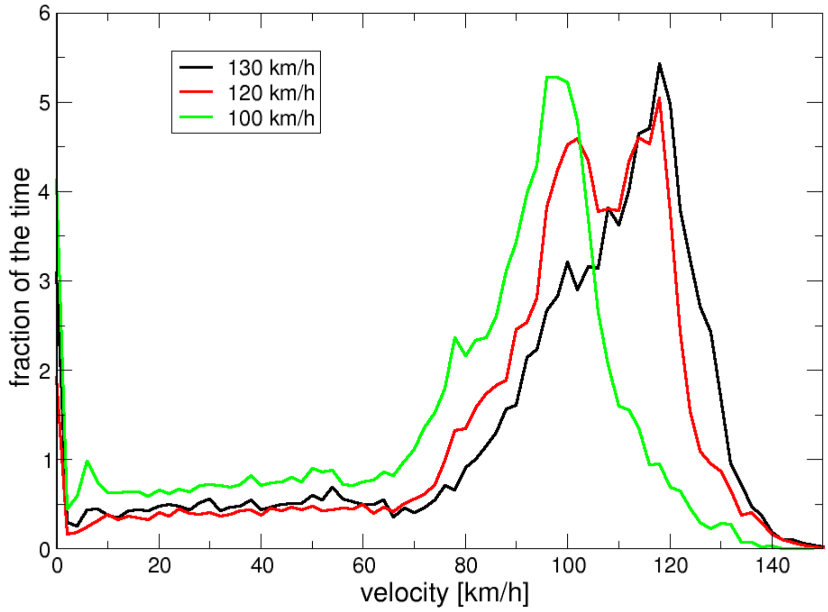


Figure 5.2: Fraction of time spent at a certain velocity, for motorway segments with different speed limits

# 6 Conclusions

The emission performance of Euro-6 diesel passenger cars and Euro VI diesel trucks was measured during test trips on the road. The emissions were measured by means of TNO's Smart Emission Measurement System (SEMS) and a Portable Emissions Measurement System (PEMS). The VERSIT+ emission calculation method was used to determine the emission factors for various road types. The $NH_3$ emissions are now also reported along with the other emission factors.

The passenger cars were also tested on a chassis dynamometer in a test laboratory, which yielded significantly lower $NO_x$ emissions. Due to the limited validity of these results for real-world emissions, they were not taken into account for this evaluation of emission factors.

Some differences were observed between the old (2015) emission factors, and the current update. The most important one being that the $NO_x$ emission factors for passenger cars increased for rural and congested driving, whereas they slightly decreased for motorway driving. Compared to Euro-5, the Euro-6 emission factors have decreased, be it not as much as the regulation limits suggest [Chapter 2].

For heavy duty vehicles, most calculated emission factors are still below the values that have previously been reported. Since it is expected that the early Euro-VI models that have been tested give a too optimistic view of the full Euro-VI fleet that will be introduced in the coming years, it was decided that the emission factors are only updated if they are higher than the ones that are currently published [Chapter 3].

The emission factors of Euro-6 passenger cars and Euro-VI trucks are determined directly from measurements. The acquired knowledge also enabled a more informed estimate of the emission factors of other Euro-5 and Euro-6 vehicle categories, which have been updated accordingly [Chapter 4].

The analysis procedure of measurement data did not change compared to previous years, with the exception of the parameters used to describe driving behaviour at different road types. They have been determined from real on-road driving behaviour of passenger cars, and yield higher average velocities and higher dynamics [Chapter 5].

The new type-approval according to Euro-6 legislation are obligatory for all vehicles from 1st September 2015. Hence, in the last quarter of 2015 there has been an influx of Euro-6 vehicles, which seem to perform less on $NO_x$ emissions than the earlier Euro-6 vehicles. Only a few of these later vehicles have been tested yet. The results came too late to be included in the emission factors update of 2016. However, it is expected that in 2017 the $NO_x$ emission factors for Euro-6 diesel passenger cars will be higher again than estimated in 2016.

Generally, only after the new legislation is compulsory for all vehicles, the commonly used emission control technology can be determined, and the emission factors will settle to an appropriate average for the years to come.

The current understanding is that LNT (Lean $NO_x$ Trap) emission control technology will be common for mainstream vehicle models. This update is still based mainly on SCR technology vehicles. The LNT technology is known to perform poorly at high and transient engine loads, which is associated with higher vehicle velocities and dynamic driving. Moreover, LNT control strategies are complex, like the three-way catalyst for petrol vehicles introduced in 1990, which may take several years to evolve into robust emission control technology for the use in all normal traffic situations.

# 7 References

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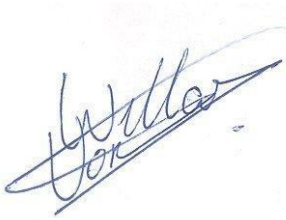
# 8 Signature

Delft, 7 March 2016

TNO

Gerrit Kadijk
Project leader

Norbert Ligterink
Author



Willar Vonk
Project leader

# A Tables

## A.1 Road type definition

Table 15: Definition of road types

| Name | Description |
|---|---|
| WS1 | Urban congestion, below 15 km/h, 10 stops per kilometre |
| WM1 | Urban normal, 15-30 km/h average, 2 stops per kilometre |
| WF1 | Urban free-flow, 30-45 km/h, 1.5 stop per kilometre |
| WT1 | Urban average, for the total national urban emissions |
| WT2 | Rural roads, 60 km/h average, for national motorway emissions |
| W80MSH (W83) | Motorway 80 km/h speed limit with strict enforcement |
| WS3 | Motorway congestion, average driving below 50 km/h |
| WT3 | Motorway average, for the total national motorway emissions |
| W100MSH (W03) | Motorway 100 km/h speed limit with strict enforcement |
| W100ZSH (W13) | Motorway 100 km/h speed limit without strict enforcement |
| W120ZSH (W23) | Motorway 120 km/h speed limit (max. Dutch limit prior to 2011) |
| W130 (W33) | Motorway 130 km/h speed limit (max. Dutch limit since 2011) |

## A.2 2016 emission factors of remaining vehicle categories

| LPADEUR5 | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.0515 | 233 | 0.00928 | | 327 | 1.00E+03 |
| WM1 | 0.0395 | 158 | 0.00602 | | 214 | 708 |
| WF1 | 0.0271 | 122 | 0.00465 | | 160 | 542 |
| WT1 | 0.035 | 152 | 0.00588 | | 206 | 675 |
| WT2 | 0.0196 | 120 | 0.00417 | | 161 | 531 |
| W80MSH | 0.0137 | 92.7 | 0.00333 | | 122 | 405 |
| WS3 | 0.044 | 165 | 0.00617 | | 227 | 746 |
| WT3 | 0.0079 | 124 | 0.00265 | | 181 | 588 |
| W100MSH | 0.0081 | 113 | 0.00275 | | 158 | 501 |
| W100ZSH | 0.00756 | 116 | 0.00264 | | 165 | 528 |
| W120ZSH | 0.00657 | 122 | 0.00244 | | 178 | 576 |
| W130 | 0.00653 | 122 | 0.00239 | | 181 | 589 |

| LPADEUC6 | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.75 | 317 | 0.0255 | 3.65 | 129 | 314 |
| WM1 | 0.565 | 246 | 0.0188 | 2.83 | 99.9 | 244 |
| WF1 | 0.356 | 190 | 0.0133 | 2.3 | 76.9 | 188 |
| WT1 | 0.487 | 231 | 0.0171 | 2.7 | 93.5 | 228 |
| WT2 | 0.255 | 172 | 0.0118 | 2.16 | 69.7 | 170 |
| W80MSH | 0.152 | 129 | 0.00822 | 1.68 | 52.3 | 127 |
| WS3 | 0.644 | 257 | 0.0205 | 2.94 | 104 | 253 |
| WT3 | 0.166 | 174 | 0.0131 | 1.86 | 70.3 | 171 |
| W100MSH | 0.142 | 140 | 0.0109 | 1.76 | 56.9 | 139 |
| W100ZSH | 0.146 | 150 | 0.0116 | 1.77 | 60.9 | 148 |
| W120ZSH | 0.153 | 168 | 0.0128 | 1.79 | 67.9 | 166 |
| W130 | 0.158 | 175 | 0.0131 | 1.79 | 70.7 | 173 |

| LBADEUR5LCH | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.0515 | 233 | 0.00928 | | 327 | 1.00E+03 |
| WM1 | 0.0395 | 158 | 0.00602 | | 214 | 708 |
| WF1 | 0.0271 | 122 | 0.00465 | | 160 | 542 |
| WT1 | 0.035 | 152 | 0.00588 | | 206 | 675 |
| WT2 | 0.0196 | 120 | 0.00417 | | 161 | 531 |
| W80MSH | 0.0137 | 92.7 | 0.00333 | | 122 | 405 |
| WS3 | 0.044 | 165 | 0.00617 | | 227 | 746 |
| WT3 | 0.0079 | 124 | 0.00265 | | 181 | 588 |
| W100MSH | 0.0081 | 113 | 0.00275 | | 158 | 501 |
| W100ZSH | 0.00756 | 116 | 0.00264 | | 165 | 528 |
| W120ZSH | 0.00657 | 122 | 0.00244 | | 178 | 576 |
| W130 | 0.00653 | 122 | 0.00239 | | 181 | 589 |

| LBADEUR5ZWA | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.0772 | 347 | 0.0117 | | 625 | 2.08E+03 |
| WM1 | 0.0593 | 256 | 0.00759 | | 501 | 1.67E+03 |
| WF1 | 0.0406 | 205 | 0.00586 | | 408 | 1.36E+03 |
| WT1 | 0.0525 | 247 | 0.0074 | | 479 | 1.60E+03 |
| WT2 | 0.0295 | 205 | 0.00526 | | 387 | 1.29E+03 |
| W80MSH | 0.0205 | 158 | 0.0042 | | 298 | 993 |
| WS3 | 0.066 | 260 | 0.00778 | | 505 | 1.68E+03 |
| WT3 | 0.0118 | 247 | 0.00333 | | 460 | 1.53E+03 |
| W100MSH | 0.0122 | 208 | 0.00347 | | 340 | 1.13E+03 |
| W100ZSH | 0.0113 | 221 | 0.00333 | | 378 | 1.26E+03 |
| W120ZSH | 0.00986 | 244 | 0.00308 | | 446 | 1.49E+03 |
| W130 | 0.0098 | 249 | 0.00301 | | 477 | 1.59E+03 |

| LBADEUA6LCH | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.75 | 317 | 0.0255 | 3.65 | 288 | 679 |
| WM1 | 0.565 | 246 | 0.0188 | 2.83 | 225 | 571 |
| WF1 | 0.356 | 190 | 0.0133 | 2.3 | 176 | 454 |
| WT1 | 0.487 | 231 | 0.0171 | 2.7 | 212 | 534 |
| WT2 | 0.255 | 172 | 0.0118 | 2.16 | 157 | 397 |
| W80MSH | 0.152 | 129 | 0.00822 | 1.68 | 122 | 310 |
| WS3 | 0.644 | 257 | 0.0205 | 2.94 | 233 | 594 |
| WT3 | 0.166 | 174 | 0.0131 | 1.86 | 165 | 404 |
| W100MSH | 0.142 | 140 | 0.0109 | 1.76 | 111 | 253 |
| W100ZSH | 0.146 | 150 | 0.0116 | 1.77 | 127 | 294 |
| W120ZSH | 0.153 | 168 | 0.0128 | 1.79 | 156 | 377 |
| W130 | 0.158 | 175 | 0.0131 | 1.79 | 174 | 434 |

| LBADEUA6ZWA | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 1.12 | 347 | 0.0321 | 3.65 | 675 | 1.65E+03 |
| WM1 | 0.848 | 256 | 0.0237 | 2.83 | 538 | 1.31E+03 |
| WF1 | 0.535 | 205 | 0.0167 | 2.3 | 427 | 1.04E+03 |
| WT1 | 0.731 | 247 | 0.0215 | 2.7 | 509 | 1.24E+03 |
| WT2 | 0.383 | 205 | 0.0148 | 2.16 | 393 | 958 |
| W80MSH | 0.227 | 158 | 0.0104 | 1.68 | 300 | 731 |
| WS3 | 0.966 | 260 | 0.0258 | 2.94 | 546 | 1.33E+03 |
| WT3 | 0.25 | 247 | 0.0165 | 1.86 | 438 | 1.07E+03 |
| W100MSH | 0.213 | 208 | 0.0137 | 1.76 | 327 | 797 |
| W100ZSH | 0.219 | 221 | 0.0146 | 1.77 | 361 | 881 |
| W120ZSH | 0.229 | 244 | 0.0161 | 1.79 | 423 | 1.03E+03 |
| W130 | 0.236 | 249 | 0.0165 | 1.79 | 452 | 1.10E+03 |

| LBADEUC6LCH | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 0.75 | 317 | 0.0255 | 3.65 | 139 | 338 |
| WM1 | 0.565 | 246 | 0.0188 | 2.83 | 108 | 263 |
| WF1 | 0.356 | 190 | 0.0133 | 2.3 | 83 | 202 |
| WT1 | 0.487 | 231 | 0.0171 | 2.7 | 101 | 246 |
| WT2 | 0.255 | 172 | 0.0118 | 2.16 | 75.2 | 183 |
| W80MSH | 0.152 | 129 | 0.00822 | 1.68 | 56.4 | 137 |
| WS3 | 0.644 | 257 | 0.0205 | 2.94 | 112 | 273 |
| WT3 | 0.166 | 174 | 0.0131 | 1.86 | 75.8 | 185 |
| W100MSH | 0.142 | 140 | 0.0109 | 1.76 | 61.3 | 150 |
| W100ZSH | 0.146 | 150 | 0.0116 | 1.77 | 65.7 | 160 |
| W120ZSH | 0.153 | 168 | 0.0128 | 1.79 | 73.2 | 179 |
| W130 | 0.158 | 175 | 0.0131 | 1.79 | 76.3 | 186 |

| LBADEUC6ZWA | CO [g/km] | $CO_2$ [g/km] | HCe [g/km] | $NH_3$ [mg/km] | $NO_2$ [mg/km] | $NO_x$ [mg/km] |
|---|---|---|---|---|---|---|
| WS1 | 1.12 | 347 | 0.0321 | 3.65 | 175 | 426 |
| WM1 | 0.848 | 256 | 0.0237 | 2.83 | 129 | 315 |
| WF1 | 0.535 | 205 | 0.0167 | 2.3 | 103 | 252 |
| WT1 | 0.731 | 247 | 0.0215 | 2.7 | 124 | 303 |
| WT2 | 0.383 | 205 | 0.0148 | 2.16 | 103 | 252 |
| W80MSH | 0.227 | 158 | 0.0104 | 1.68 | 79.4 | 194 |
| WS3 | 0.966 | 260 | 0.0258 | 2.94 | 131 | 320 |
| WT3 | 0.25 | 247 | 0.0165 | 1.86 | 124 | 303 |
| W100MSH | 0.213 | 208 | 0.0137 | 1.76 | 105 | 255 |
| W100ZSH | 0.219 | 221 | 0.0146 | 1.77 | 111 | 272 |
| W120ZSH | 0.229 | 244 | 0.0161 | 1.79 | 123 | 299 |
| W130 | 0.236 | 249 | 0.0165 | 1.79 | 125 | 305 |

## A.3 Euro-VI diesel truck emission factor tables

### A.3.1 MVADEUR6LCH emission factors

Table 16: Emission factors, as calculated for 2016 update, for MVADEUR6LCH

| MVADEUR6LCH, Rigid Truck Light, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO EF** | **CO2 EF** | **HCe EF** | **NO2 EF** | **NOx EF** |
| | **g/km** | **g/km** | **g/km** | **g/km** | **g/km** |
| **WT1** | 0.680 | 382.038 | 0.076 | 0.030 | 0.161 |
| **WT2** | 0.380 | 282.812 | 0.043 | 0.041 | 0.114 |
| **WT3** | 0.288 | 260.027 | 0.038 | 0.049 | 0.071 |
| **WS1** | 1.087 | 611.261 | 0.121 | 0.048 | 0.258 |
| **WM1** | 0.680 | 382.038 | 0.076 | 0.030 | 0.161 |
| **WF1** | 0.483 | 271.247 | 0.054 | 0.021 | 0.115 |
| **WS3** | 0.680 | 382.038 | 0.076 | 0.030 | 0.161 |

Table 17: Current, i.e. as published in 2015, emission factors for MVADEUR6LCH

| MVADEUR6LCH, Rigid Truck Light, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO EF** | **CO2 EF** | **HCe EF** | **NO2 EF** | **NOx EF** |
| | **g/km** | **g/km** | **g/km** | **g/km** | **g/km** |
| **WT1** | 0.736 | 392.973 | 0.009 | 0.097 | 0.278 |
| **WT2** | 0.379 | 272.627 | 0.006 | 0.068 | 0.193 |
| **WT3** | 0.270 | 241.300 | 0.004 | 0.060 | 0.171 |
| **WS1** | 1.178 | 628.758 | 0.015 | 0.156 | 0.445 |
| **WM1** | 0.736 | 392.973 | 0.009 | 0.097 | 0.278 |
| **WF1** | 0.523 | 279.011 | 0.007 | 0.069 | 0.197 |
| **WS3** | 0.736 | 392.973 | 0.009 | 0.097 | 0.278 |

Table 18: Relative differences between 2015 and 2016 emission factors

| MVADEUR6LCH, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| Road Type | CO ΔEF | CO2 ΔEF | HCe ΔEF | NO2 ΔEF | NOx ΔEF |
| | % | % | % | % | % |
| WT1 | -7.68 | -2.78 | 706.13 | -69.06 | -41.95 |
| WT2 | 0.17 | 3.74 | 664.69 | -39.50 | -41.06 |
| WT3 | 6.48 | 7.76 | 904.13 | -18.18 | -58.32 |
| WS1 | -7.68 | -2.78 | 706.20 | -69.06 | -41.95 |
| WM1 | -7.68 | -2.78 | 706.13 | -69.06 | -41.95 |
| WF1 | -7.68 | -2.78 | 706.22 | -69.06 | -41.95 |
| WS3 | -7.68 | -2.78 | 706.13 | -69.06 | -41.95 |

### A.3.2 MVADEUR6ZWA emission factors

Table 19: Emission factors, as calculated for 2016 update, for MVADEUR6ZWA

| MVADEUR6ZWA, Rigid Truck Heavy, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.367 | 799.424 | 0.135 | 0.080 | 0.331 |
| WT2 | 0.764 | 579.825 | 0.078 | 0.086 | 0.224 |
| WT3 | 0.567 | 511.084 | 0.069 | 0.091 | 0.137 |
| WS1 | 2.187 | 1279.078 | 0.216 | 0.129 | 0.529 |
| WM1 | 1.367 | 799.424 | 0.135 | 0.080 | 0.331 |
| WF1 | 0.971 | 567.591 | 0.096 | 0.057 | 0.235 |
| WS3 | 1.367 | 799.424 | 0.135 | 0.080 | 0.331 |

Table 20: Current, i.e. as published in 2015, emission factors for MVADEUR6ZWA

| MVADEUR6ZWA, Rigid Truck Heavy, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.436 | 818.183 | 0.017 | 0.203 | 0.579 |
| WT2 | 0.735 | 556.555 | 0.010 | 0.138 | 0.394 |
| WT3 | 0.515 | 479.299 | 0.007 | 0.119 | 0.339 |
| WS1 | 2.298 | 1309.090 | 0.027 | 0.324 | 0.926 |
| WM1 | 1.436 | 818.183 | 0.017 | 0.203 | 0.579 |
| WF1 | 1.020 | 580.910 | 0.012 | 0.144 | 0.411 |
| WS3 | 1.436 | 818.183 | 0.017 | 0.203 | 0.579 |

Table 21: Relative differences between 2015 and 2016 emission factors

| MVADEUR6ZWA, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO ΔEF** | **CO2 ΔEF** | **HCe ΔEF** | **NO2 ΔEF** | **NOx ΔEF** |
| | **%** | **%** | **%** | **%** | **%** |
| **WT1** | -4.82 | -2.29 | 700.75 | -60.30 | -42.88 |
| **WT2** | 3.85 | 4.18 | 682.53 | -37.97 | -43.09 |
| **WT3** | 10.09 | 6.63 | 936.48 | -23.53 | -59.71 |
| **WS1** | -4.82 | -2.29 | 700.75 | -60.30 | -42.88 |
| **WM1** | -4.82 | -2.29 | 700.75 | -60.30 | -42.88 |
| **WF1** | -4.82 | -2.29 | 700.77 | -60.30 | -42.88 |
| **WS3** | -4.82 | -2.29 | 700.75 | -60.30 | -42.88 |

## A.3.3 ZVADEUR6 emission factors

Table 22: Emission factors, as calculated for 2016 update, for ZVADEUR6

| ZVADEUR6, Heavy Rigid Truck, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO EF** | **CO2 EF** | **HCe EF** | **NO2 EF** | **NOx EF** |
| | **g/km** | **g/km** | **g/km** | **g/km** | **g/km** |
| **WT1** | 1.911 | 1186.272 | 0.151 | 0.157 | 0.476 |
| **WT2** | 1.066 | 834.857 | 0.093 | 0.127 | 0.303 |
| **WT3** | 0.765 | 687.871 | 0.082 | 0.110 | 0.177 |
| **WS1** | 3.058 | 1898.035 | 0.242 | 0.251 | 0.761 |
| **WM1** | 1.911 | 1186.272 | 0.151 | 0.157 | 0.476 |
| **WF1** | 1.357 | 842.253 | 0.107 | 0.111 | 0.338 |
| **WS3** | 1.911 | 1186.272 | 0.151 | 0.157 | 0.476 |

Table 23: Current, i.e. as published in 2015, emission factors for ZVADEUR6

| ZVADEUR6, Heavy Rigid Truck, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO EF** | **CO2 EF** | **HCe EF** | **NO2 EF** | **NOx EF** |
| | **g/km** | **g/km** | **g/km** | **g/km** | **g/km** |
| **WT1** | 1.911 | 1208.150 | 0.019 | 0.299 | 0.855 |
| **WT2** | 0.967 | 797.987 | 0.011 | 0.198 | 0.565 |
| **WT3** | 0.653 | 655.666 | 0.007 | 0.162 | 0.464 |
| **WS1** | 3.057 | 1933.050 | 0.031 | 0.479 | 1.368 |
| **WM1** | 1.911 | 1208.150 | 0.019 | 0.299 | 0.855 |
| **WF1** | 1.357 | 857.790 | 0.014 | 0.212 | 0.607 |
| **WS3** | 1.911 | 1208.150 | 0.019 | 0.299 | 0.855 |

Table 24: Relative differences between 2015 and 2016 emission factors

| ZVADEUR6, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| Road Type | CO ΔEF | CO2 ΔEF | HCe ΔEF | NO2 ΔEF | NOx ΔEF |
| | % | % | % | % | % |
| WT1 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |
| WT2 | 10.25 | 4.62 | 723.91 | -35.78 | -46.32 |
| WT3 | 17.23 | 4.91 | 1012.01 | -32.21 | -61.95 |
| WS1 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |
| WM1 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |
| WF1 | 0.03 | -1.81 | 690.29 | -47.66 | -44.38 |
| WS3 | 0.03 | -1.81 | 690.30 | -47.66 | -44.38 |

### A.3.4 ZVADEUR6ANHLCH emission factors

Table 25: Emission factors, as calculated for 2016 update, for ZVADEURANH6LCH

| ZVADEUR6ANHLCH, Heavy Rigid Truck w. Trailer Light, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.613 | 1181.352 | 0.080 | 0.201 | 0.435 |
| WT2 | 0.915 | 741.571 | 0.062 | 0.111 | 0.218 |
| WT3 | 0.700 | 627.965 | 0.055 | 0.081 | 0.152 |
| WS1 | 2.581 | 1890.163 | 0.128 | 0.321 | 0.696 |
| WM1 | 1.613 | 1181.352 | 0.080 | 0.201 | 0.435 |
| WF1 | 1.145 | 838.760 | 0.057 | 0.142 | 0.309 |
| WS3 | 1.613 | 1181.352 | 0.080 | 0.201 | 0.435 |

Table 26: Current, i.e. as published in 2015, emission factors for ZVADEURANH6LCH

| ZVADEUR6ANHLCH, Heavy Rigid Truck w. Trailer Light, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.435 | 1169.750 | 0.010 | 0.290 | 0.828 |
| WT2 | 0.737 | 720.655 | 0.006 | 0.179 | 0.510 |
| WT3 | 0.530 | 616.593 | 0.004 | 0.153 | 0.436 |
| WS1 | 2.296 | 1871.600 | 0.016 | 0.464 | 1.325 |
| WM1 | 1.435 | 1169.750 | 0.010 | 0.290 | 0.828 |
| WF1 | 1.019 | 830.524 | 0.007 | 0.206 | 0.588 |
| WS3 | 1.435 | 1169.750 | 0.010 | 0.290 | 0.828 |

Table 27: Relative differences between 2015 and 2016 emission factors

| ZVADEUR6ANHLCH, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | % | % | % | % | % |
| WT1 | 12.41 | 0.99 | 687.20 | -30.78 | -47.43 |
| WT2 | 24.06 | 2.90 | 977.81 | -38.03 | -57.16 |
| WT3 | 32.03 | 1.84 | 1246.18 | -46.90 | -65.18 |
| WS1 | 12.41 | 0.99 | 687.21 | -30.78 | -47.43 |
| WM1 | 12.41 | 0.99 | 687.20 | -30.78 | -47.43 |
| WF1 | 12.41 | 0.99 | 687.17 | -30.78 | -47.43 |
| WS3 | 12.41 | 0.99 | 687.20 | -30.78 | -47.43 |

## A.3.5 ZVADEUR6ANHZWA emission factors

Table 28: Emission factors, as calculated for 2016 update, for ZVADEURANH6ZWA

| ZVADEUR6ANHZWA, Heavy Rigid Truck w. Trailer Heavy, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 2.273 | 1733.925 | 0.079 | 0.320 | 0.615 |
| WT2 | 1.273 | 1045.329 | 0.068 | 0.152 | 0.299 |
| WT3 | 0.958 | 857.622 | 0.060 | 0.098 | 0.199 |
| WS1 | 3.637 | 2774.281 | 0.126 | 0.513 | 0.984 |
| WM1 | 2.273 | 1733.925 | 0.079 | 0.320 | 0.615 |
| WF1 | 1.614 | 1231.087 | 0.056 | 0.228 | 0.437 |
| WS3 | 2.273 | 1733.925 | 0.079 | 0.320 | 0.615 |

Table 29: Current, i.e. as published in 2015, emission factors for ZVADEURANH6ZWA

| ZVADEUR6ANHZWA, Heavy Rigid Truck w. Trailer Heavy, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.927 | 1707.520 | 0.010 | 0.423 | 1.208 |
| WT2 | 0.967 | 1018.210 | 0.005 | 0.252 | 0.721 |
| WT3 | 0.678 | 857.862 | 0.004 | 0.212 | 0.607 |
| WS1 | 3.082 | 2732.030 | 0.016 | 0.677 | 1.933 |
| WM1 | 1.927 | 1707.520 | 0.010 | 0.423 | 1.208 |
| WF1 | 1.368 | 1212.340 | 0.007 | 0.300 | 0.858 |
| WS3 | 1.927 | 1707.520 | 0.010 | 0.423 | 1.208 |

Table 30: Relative differences between 2015 and 2016 emission factors

| ZVADEUR6ANHZWA, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| Road Type | CO ΔEF | CO2 ΔEF | HCe ΔEF | NO2 ΔEF | NOx ΔEF |
| | % | % | % | % | % |
| WT1 | 17.98 | 1.55 | 694.24 | -24.22 | -49.10 |
| WT2 | 31.59 | 2.66 | 1182.66 | -39.55 | -58.53 |
| WT3 | 41.36 | -0.03 | 1540.54 | -54.01 | -67.24 |
| WS1 | 17.98 | 1.55 | 694.25 | -24.22 | -49.10 |
| WM1 | 17.98 | 1.55 | 694.24 | -24.22 | -49.10 |
| WF1 | 17.98 | 1.55 | 694.25 | -24.22 | -49.10 |
| WS3 | 17.98 | 1.55 | 694.24 | -24.22 | -49.10 |

### A.3.6 ZTRDEUR6LCH emission factors

Table 31: Emission factors, as calculated for 2016 update, for ZTRDEUR6LCH

| ZTRDEUR6LCH, Tractor Semi-Trailer Light, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.884 | 1164.105 | 0.152 | 0.151 | 0.468 |
| WT2 | 1.051 | 821.025 | 0.093 | 0.125 | 0.300 |
| WT3 | 0.756 | 679.897 | 0.082 | 0.110 | 0.175 |
| WS1 | 3.014 | 1862.569 | 0.243 | 0.242 | 0.748 |
| WM1 | 1.884 | 1164.105 | 0.152 | 0.151 | 0.468 |
| WF1 | 1.337 | 826.515 | 0.108 | 0.107 | 0.332 |
| WS3 | 1.884 | 1164.105 | 0.152 | 0.151 | 0.468 |

Table 32: Current, i.e. as published in 2015, emission factors for ZTRDEUR6LCH

| ZTRDEUR6LCH, Tractor Semi-Trailer Light, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| Road Type | CO EF | CO2 EF | HCe EF | NO2 EF | NOx EF |
| | g/km | g/km | g/km | g/km | g/km |
| WT1 | 1.890 | 1186.070 | 0.019 | 0.294 | 0.839 |
| WT2 | 0.957 | 785.050 | 0.011 | 0.194 | 0.556 |
| WT3 | 0.648 | 647.206 | 0.007 | 0.160 | 0.458 |
| WS1 | 3.024 | 1897.710 | 0.031 | 0.470 | 1.343 |
| WM1 | 1.890 | 1186.070 | 0.019 | 0.294 | 0.839 |
| WF1 | 1.342 | 842.107 | 0.014 | 0.209 | 0.596 |
| WS3 | 1.890 | 1186.070 | 0.019 | 0.294 | 0.839 |

Table 33: Relative differences between 2015 and 2016 emission factors

| ZTRDEUR6LCH, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO ΔEF** | **CO2 ΔEF** | **HCe ΔEF** | **NO2 ΔEF** | **NOx ΔEF** |
| | **%** | **%** | **%** | **%** | **%** |
| **WT1** | -0.35 | -1.85 | 691.29 | -48.56 | -44.28 |
| **WT2** | 9.75 | 4.58 | 720.17 | -35.94 | -46.08 |
| **WT3** | 16.69 | 5.05 | 1005.08 | -31.55 | -61.77 |
| **WS1** | -0.35 | -1.85 | 691.28 | -48.56 | -44.28 |
| **WM1** | -0.35 | -1.85 | 691.29 | -48.56 | -44.28 |
| **WF1** | -0.35 | -1.85 | 691.29 | -48.56 | -44.28 |
| **WS3** | -0.35 | -1.85 | 691.29 | -48.56 | -44.28 |

### A.3.7 ZTRDEUR6ZWA emission factors

Table 34: Emission factors, as calculated for 2016 update, for ZTRDEUR6ZWA

| ZTRDEUR6ZWA, Tractor Semi-Trailer Heavy, 2016 EFs | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO EF** | **CO2 EF** | **HCe EF** | **NO2 EF** | **NOx EF** |
| | **g/km** | **g/km** | **g/km** | **g/km** | **g/km** |
| **WT1** | 2.839 | 2080.546 | 0.052 | 0.437 | 0.768 |
| **WT2** | 1.577 | 1352.771 | 0.059 | 0.223 | 0.403 |
| **WT3** | 1.012 | 898.786 | 0.054 | 0.086 | 0.195 |
| **WS1** | 4.542 | 3328.873 | 0.082 | 0.699 | 1.228 |
| **WM1** | 2.839 | 2080.546 | 0.052 | 0.437 | 0.768 |
| **WF1** | 2.016 | 1477.187 | 0.037 | 0.310 | 0.545 |
| **WS3** | 2.839 | 2080.546 | 0.052 | 0.437 | 0.768 |

Table 35: Current, i.e. as published in 2015, emission factors for ZTRDEUR6ZWA

| ZTRDEUR6ZWA, Tractor Semi-Trailer Heavy, 2015 EFs | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO EF** | **CO2 EF** | **HCe EF** | **NO2 EF** | **NOx EF** |
| | **g/km** | **g/km** | **g/km** | **g/km** | **g/km** |
| **WT1** | 2.385 | 2088.690 | 0.008 | 0.517 | 1.478 |
| **WT2** | 1.153 | 1274.750 | 0.004 | 0.316 | 0.902 |
| **WT3** | 0.673 | 910.832 | 0.002 | 0.226 | 0.645 |
| **WS1** | 3.816 | 3341.910 | 0.012 | 0.828 | 2.365 |
| **WM1** | 2.385 | 2088.690 | 0.008 | 0.517 | 1.478 |
| **WF1** | 1.693 | 1482.970 | 0.006 | 0.367 | 1.049 |
| **WS3** | 2.385 | 2088.690 | 0.008 | 0.517 | 1.478 |

Table 36: Relative differences between 2015 and 2016 emission factors

| ZTRDEUR6ZWA, ΔEF = 100*(EF_2016 - EF_2015)/EF_2015 | | | | | |
|---|---|---|---|---|---|
| **Road Type** | **CO ΔEF** | **CO2 ΔEF** | **HCe ΔEF** | **NO2 ΔEF** | **NOx ΔEF** |
| | **%** | **%** | **%** | **%** | **%** |
| **WT1** | 19.03 | -0.39 | 562.62 | -15.51 | -48.06 |
| **WT2** | 36.76 | 6.12 | 1400.33 | -29.44 | -55.31 |
| **WT3** | 50.34 | -1.32 | 2707.29 | -62.05 | -69.70 |
| **WS1** | 19.03 | -0.39 | 562.65 | -15.51 | -48.06 |
| **WM1** | 19.03 | -0.39 | 562.62 | -15.51 | -48.06 |
| **WF1** | 19.03 | -0.39 | 562.68 | -15.51 | -48.06 |
| **WS3** | 19.03 | -0.39 | 562.62 | -15.51 | -48.06 |