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TNO report

TNO 2018 R11145

Aspects of the transition from NEDC to WLTP for CO_2 values of passenger cars - phase 2: preliminary findings

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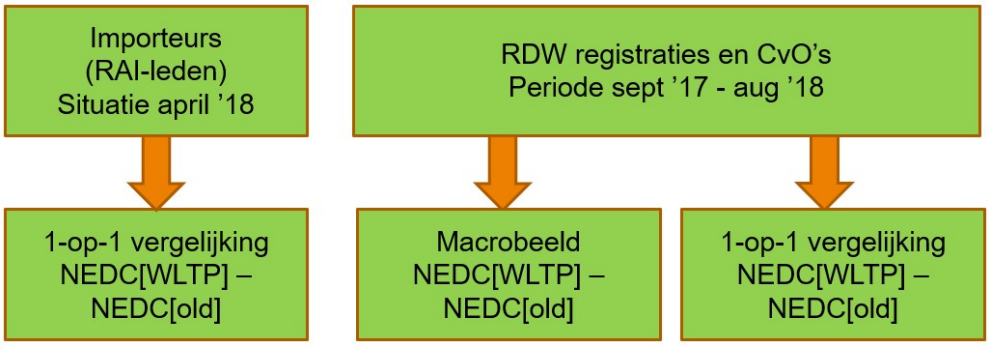
Samenvatting

TNO heeft opdracht gekregen om eventuele veranderingen van de CO_2-uitstoot ten gevolge van de introductie van de WLTP in beeld te brengen en te verklaren. In fase 1 van het project is uitleg gegeven over (de complexiteit van) de conversie van NEDC naar WLTP[1]. Het onderhavige rapport presenteert de resultaten van fase 2, de eerste kwantitatieve analyses die zijn uitgevoerd op gegevens met zichtdatum 1 september 2018. Op dat moment waren nog onvoldoende gegevens beschikbaar om een volledig representatief beeld te kunnen schetsen van de consequenties van de introductie van de WLTP op de CO_2-waarden van nieuwe personenauto's. Als de snelle toename van de hoeveelheid beschikbare data de komende maanden doorzet, kan naar verwachting in fase 3 (oplevering mei 2019) wel een goed beeld worden gepresenteerd.

Voor de analyses in fase 2 is gebruik gemaakt van databronnen van auto-importeurs, die lid zijn van de RAI-Vereniging, en van de RDW. De analyses zijn vooral toegespitst op het verschil tussen de CO_2-waarden volgens de oude NEDC methode (NEDC-auto's met NEDC[old] CO_2-waarden) en de CO_2-waarden die zijn afgeleid volgens de nieuwe WLTP methode (WLTP-auto's met NEDC[WLTP] CO_2-waarden). Om een relevante vergelijking te kunnen maken, is het van belang dat de geselecteerde NEDC-auto zoveel mogelijk gelijkenis heeft met de nieuwe WLTP-auto. In de dataset van de auto-importeurs is die selectie gedaan door de importeurs zelf. Voor de RDW datasets is de koppeling tussen NEDC- en WLTP-auto gemaakt op basis van voertuigkenmerken. De analyses geven zowel het macrobeeld – de ontwikkeling van het verschil in gemiddelde CO_2-waarden van alle verkochte WLTP- en NEDC-auto's – als ook een beeld op individueel voertuig niveau – het verschil in CO_2-waarden van nieuwe WLTP- en NEDC-auto's van zelfde merk, model en uitvoering.

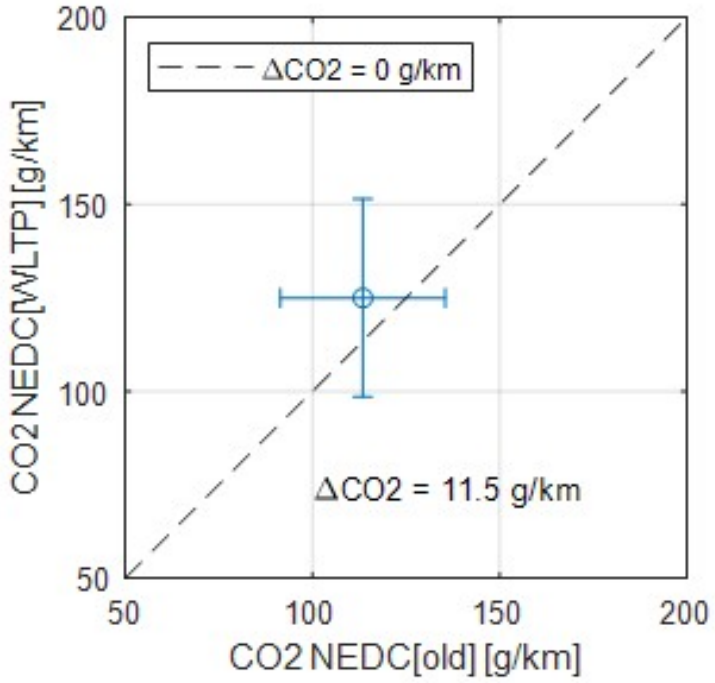
[1] https://www.rijksoverheid.nl/documenten/kamerstukken/2018/07/05/onderzoek-tno-naar-aspecten-van-de-nedc-wltp-overgang-in-relatie-tot-co2-waarden-van-personenauto's (TNO rapport R10732 (2018)).



Figuur SN-1: Overzicht van in fase 2 gebruikte datasets voor vergelijking van NEDC CO_2-waarden van WLTP- en NEDC-auto's.

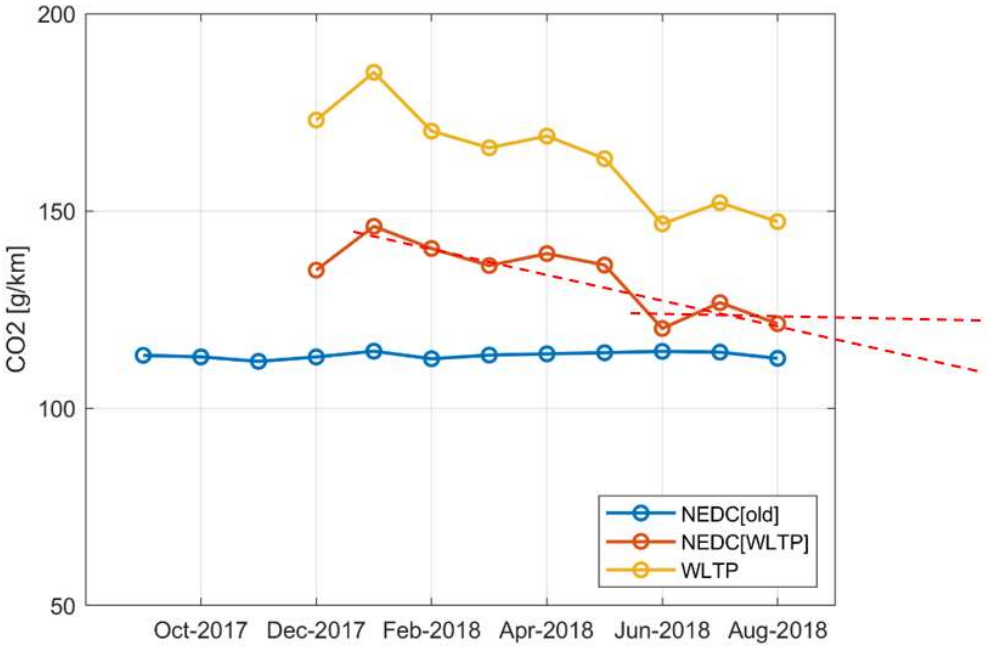
Hoofdbevindingen

Uit de 1-op-1 vergelijking van zowel de RDW- als RAI-dataset volgt een gemiddelde afwijking tussen de CO_2-waarden van een WLTP-auto en het best vergelijkbare voorgaande NEDC-model van 11-12 g/km. Daarbij is een weging toegepast op basis van het aandeel van een auto in de autoverkopen van het afgelopen jaar. Zo is getracht de resultaten representatiever te laten zijn voor de automarkt in Nederland.



Figuur SN-2: De gemiddelde afwijking en standaard deviatie tussen de NEDC[WLTP] en NEDC[old] CO_2-waarden voor de 1-op-1 vergelijking uit het RDW databestand. De standaard deviatie is fors groter dan het berekende gemiddelde verschil.

Het macrobeeld op basis van de daadwerkelijke registraties bij de RDW laat zien dat het verschil tussen de gemiddelde NEDC[WLTP] en gemiddelde NEDC[old] CO_2-waarden vanaf begin 2018 sterk is afgenomen (zie Figuur SN-3), met de toenemende aantallen registraties. In de maand augustus 2018 bedroeg het verschil 9 g/km.



Figuur SN-3: Verloop van de maandelijks gemiddelde NEDC[WLTP] en NEDC[old] CO_2-waarden in de registraties van de RDW. De ingetekende trendlijnen weerspiegelen de onzekerheid over de ontwikkeling in de komende maanden. De maandelijks gemiddelde WLTP CO_2-waarden zijn bepaald door de registraties te koppelen aan bij de RDW beschikbare CvO's.

De verwachting is dat de gemiddelde NEDC[old] CO_2-waarde de komende maanden nog iets zal afnemen. Na 1 september 2018 mogen alleen nog NEDC-auto's in Nederland worden verkocht als deze reeds geproduceerd, in de EU zijn en voor half september bij de RDW zijn geregistreerd als onderdeel van de 'restantvoorraadregeling'. In totaal zijn 90.000 auto's aangemeld onder deze regeling. Dat aantal is vergelijkbaar met het verkoopvolume in de laatste 3-4 maanden van een normaal jaar. De gemiddelde NEDC[old] CO_2-waarde van de restantvoorraad is ruim 3 g/km lager dan die van de auto's verkocht in het afgelopen jaar. Het is niet gezegd dat alle auto's uit de restantvoorraad ook daadwerkelijk in Nederland zullen worden verkocht. Ook kunnen er nog NEDC[old] auto's geïmporteerd worden.

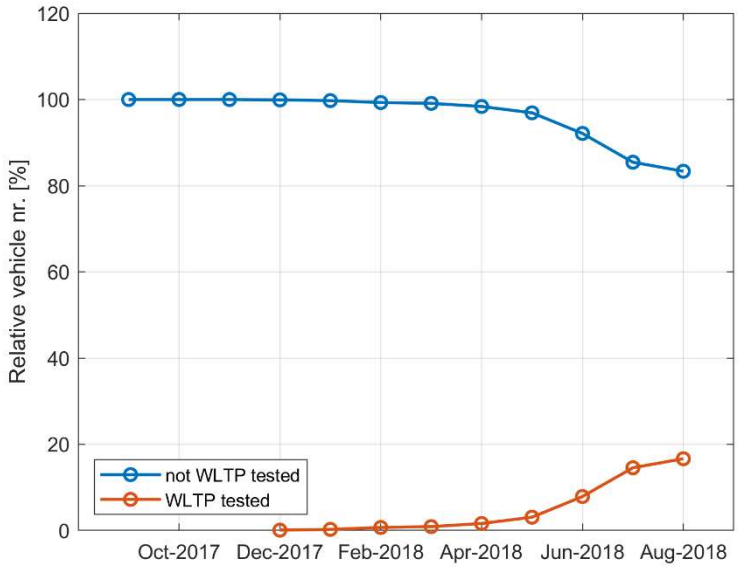
Tabel SN-1: Gemiddelde NEDC[old] CO_2-waarden van auto's aangemeld voor de restantvoorraadregeling en de auto's verkocht in de periode september 2017 – augustus 2018. Bron: RDW, eenmalige specifieke datalevering ten behoeve van dit project.

NEDC[old] (g/km)	NEDC-auto's geregistreerd tussen sept '17 en aug '18	NEDC-auto's aangemeld als restantvoorraad
Benzine	113,7	108,1
Diesel	112,1	130,8
Totaal	113,5	110,0

Gezien het verloop van het macrobeeld in de laatste drie maanden (zie Figuur SN-3) valt niet te voorspellen hoe het macrobeeld zich in de nabije toekomst zal ontwikkelen: het kan tussen 0 en 10 g/km uitkomen eind 2018. De onzekerheid wordt versterkt doordat het macrobeeld een andere ontwikkeling vertoont dan de 1-op-1 vergelijkingen. Geen van de beelden kan als volledig representatief worden bestempeld.

Aan de kant van het macrobeeld kan dat te maken hebben met het geringe aandeel WLTP-auto's binnen de totale registratie; in augustus 2018 was het aandeel 17% (zie Figuur SN-4). Het kan zijn dat vooral WLTP-auto's worden geregistreerd, waarvan de NEDC-versie al nagenoeg "WLTP-rijp" was. Ook lijkt de groep kleinere, lichtere auto's in de WLTP-registraties ondervertegenwoordigd (zie Figuur SN-10).

Aan de kant van de 1-op-1 vergelijkingen missen automerken en modellen. De RAI-dataset is omvangrijk, maar niet volledig dekkend. De 1-op-1 vergelijking op basis van de RDW-dataset kon slechts op een beperkt aantal modellen worden uitgevoerd.

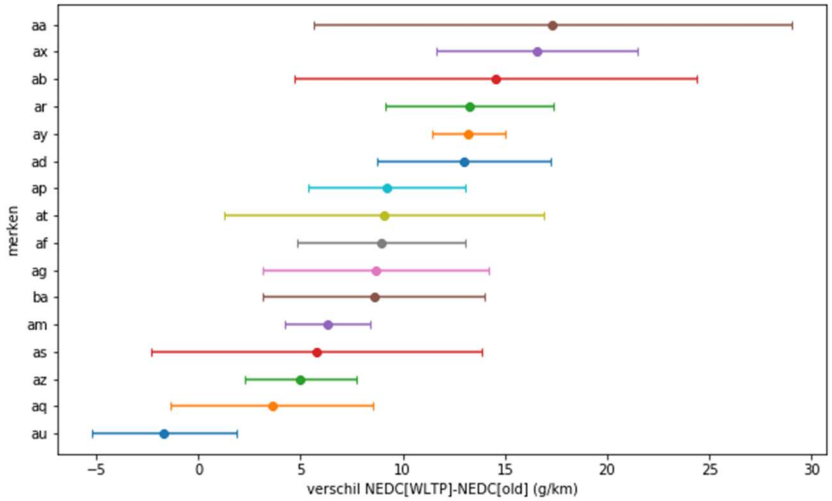


Figuur SN-4: Het maandelijkse aandeel WLTP-auto's in de nieuwe registraties bij de RDW in de periode september 2017 – augustus 2018 in procenten. In augustus bedroeg het aandeel 17%.

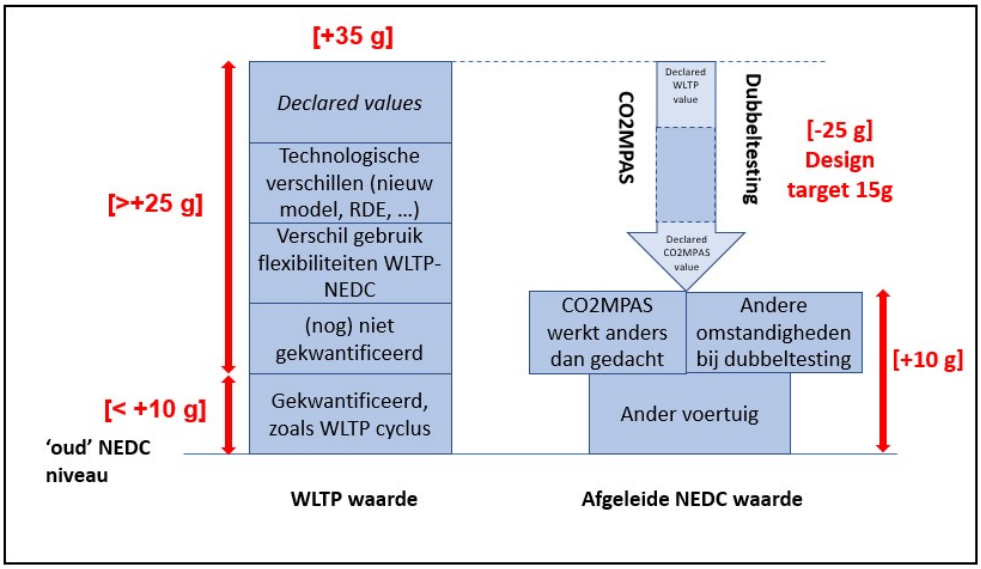
Andere elementen die bijdragen aan de onzekerheid in de toekomstige ontwikkeling van het macrobeeld:

- De standaarddeviaties van nagenoeg alle uitkomsten zijn vergelijkbaar of groter dan het berekende effect (zie onder meer Figuur SN-2).
- Er is een heel groot verschil tussen de automerken; dit duidt er op dat iedere fabrikant anders omgaat met de NEDC-WLTP conversie (zie Figuur SN-5).

- De elementen die het verschil bepalen tussen de WLTP en de oude NEDC-methode kunnen slechts in zeer beperkte mate worden gekwantificeerd. Hierdoor zijn de waargenomen effecten niet of slechts beperkt verklaarbaar (zie Figuur SN-6).



Figuur SN-5: De gemiddelde afwijking en de spreiding in NEDC[WLTP] en NEDC[old] CO_2-waarden bij verschillende automerken uit de RAI-dataset. De merken zijn geanonimiseerd.

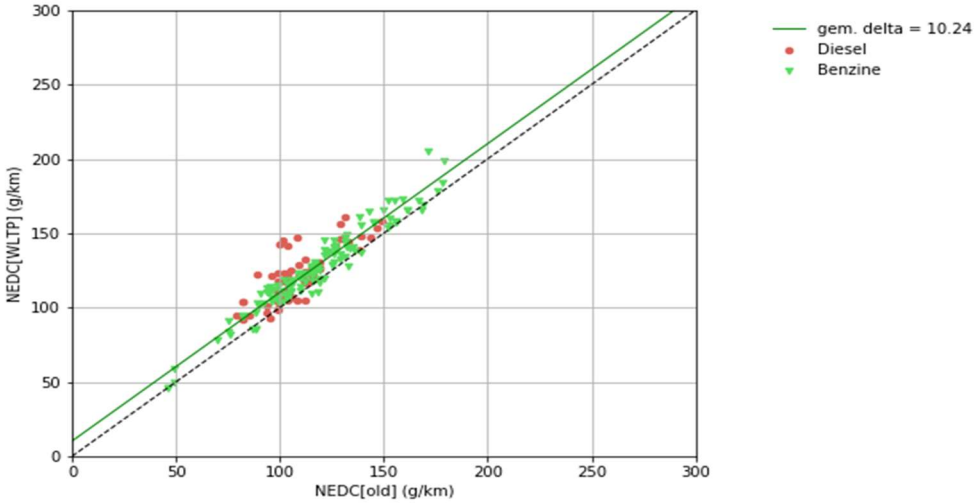


Figuur SN-6: Schematisch overzicht van elementen die het verschil bepalen tussen de WLTP en de oude NEDC-methode. De weergegeven blokken zijn geen indicatie van de omvang van het effect. De elementen kunnen slechts in zeer beperkte mate worden gekwantificeerd. De figuur is een actualisatie van de vergelijkbare figuur in het fase 1 rapport: ook bij de omrekening van WLTP CO_2-waarden naar NEDC[WLTP] CO_2-waarden kan sprake zijn van opgegeven waarden (*declared values*).

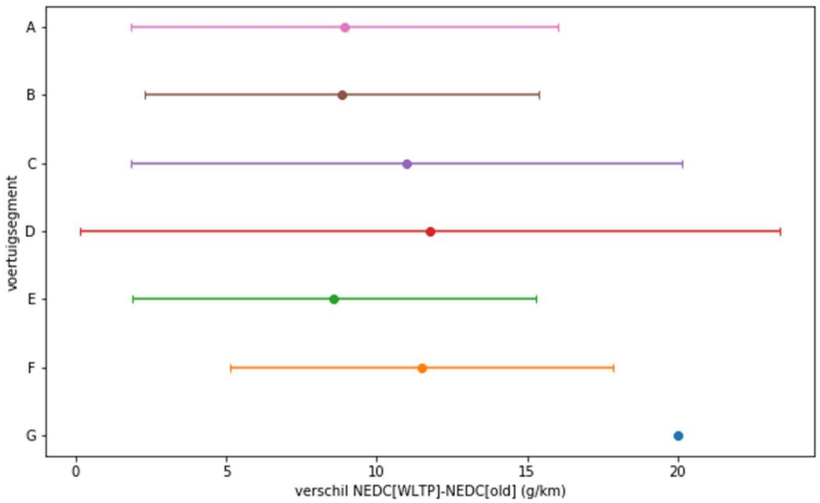
Specifieke bevindingen

Er zijn geen aanwijzingen gevonden dat het verschil tussen NEDC[WLTP] en NEDC[old] een relatie heeft met de CO_2-waarde van een auto (zie Figuur SN-7) of met het voertuigsegment (zie Figuur SN-8).

Het verschil heeft een absolute omvang van 10-12 g/km, ongeacht de grootte van het voertuig. Ook hier geldt dat de spreiding in de individuele verschillen (veel) groter is dan het waargenomen verschil zelf.

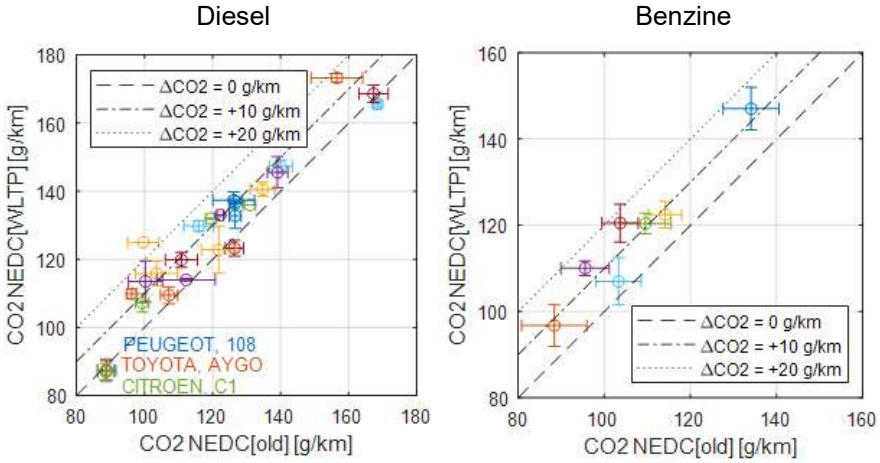


Figuur SN-7: De NEDC[WLTP] CO_2-waarden uitgezet tegen de NEDC[old] CO_2-waarden voor auto's uit de RAI-dataset, waarvoor een CvO beschikbaar was. Een (absoluut) verschil van ruim 10 g/km geeft de beste fit in deze dataset.



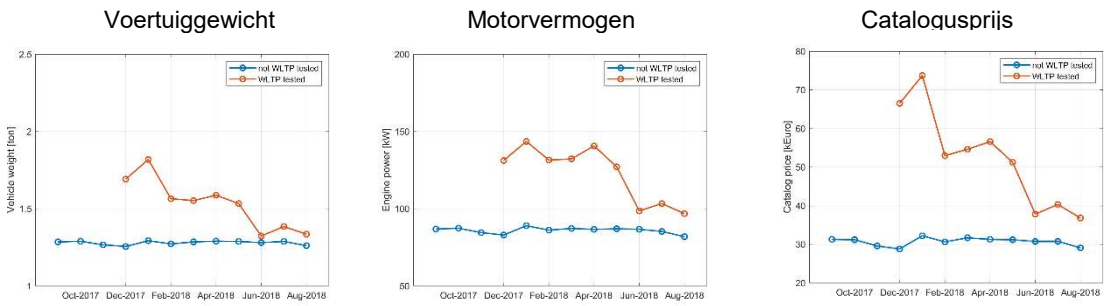
Figuur SN-8: Het gemiddelde verschil en de spreiding tussen de NEDC[WLTP] CO_2-waarden en NEDC[old] CO_2-waarden weergegeven per voertuigsegment (A t/m G), gebaseerd op de RAI-dataset van auto's waarvoor een CvO beschikbaar was.

Er is wel een verschil waarneembaar tussen benzine- en dieselauto's. Het verschil tussen de gemiddelde NEDC[WLTP] en NEDC[old] CO_2-waarde is ongeveer 4 g/km groter voor dieselauto's dan voor benzineauto's. Dit hangt onder meer samen met de grotere technische aanpassingen aan de dieselauto die nodig zijn om aan de gelijktijdige introductie van de RDE wetgeving te voldoen en met de waarneming dat de WLTP in het begin vooral op grotere en zwaardere diesels is geïntroduceerd.



Figuur SN-9: De NEDC[WLTP] en NEDC[old] CO_2-waarden en hun spreiding tegen elkaar uitgezet voor diesel- (rechts) en benzineauto's (links), gebaseerd op de RDW-dataset voor auto's waarvoor een 1-op-1 vergelijking kon worden uitgevoerd.

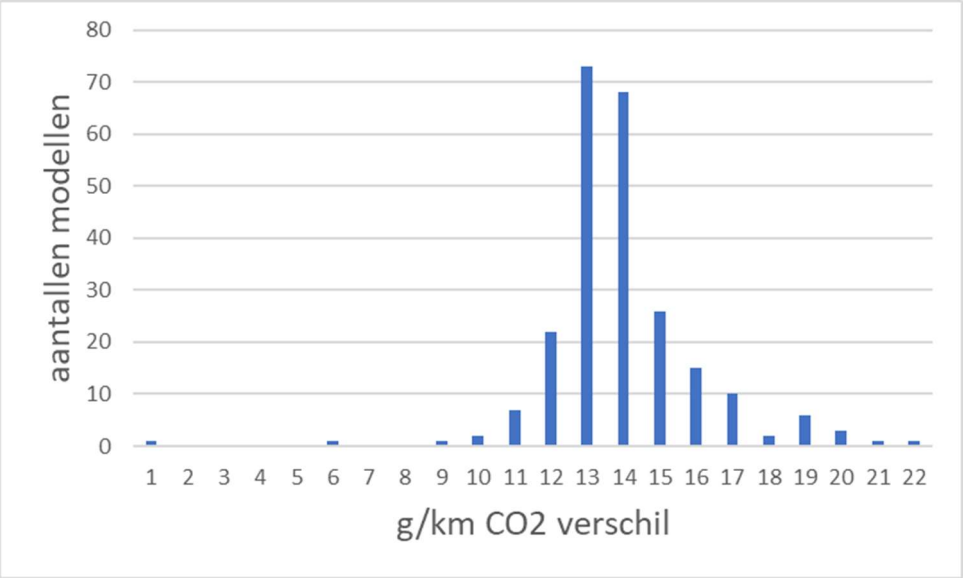
De WLTP-auto's zijn zo zorgvuldig mogelijk gekoppeld aan het best vergelijkbare vorige model NEDC-auto. Toch is er met de introductie van de WLTP sprake van een nieuw voertuig, dat afwijkt van het NEDC-voertuig. De WLTP-auto's die in eerste instantie werden geregistreerd waren veel duurder en zwaarder en hadden veel meer motorvermogen. Na mei 2018 lijkt er een sterke convergentie richting de gemiddelde NEDC-auto op te treden, maar nog steeds is er een verschil. Auto's met hoger gewicht en meer motorvermogen hebben in het algemeen ook een hogere CO_2-waarde. Volgens verwachting vertonen de verschillen in voertuigkenmerken tussen WLTP- en NEDC-auto's dezelfde trend als het macrobeeld van het verschil in NEDC[WLTP] en NEDC[old]. Met behulp van lineaire regressie is getracht het verschil in voertuigkenmerken te corrigeren. Indien de WLTP- en NEDC-auto's dezelfde voertuigkenmerken, gewicht en vermogen, zouden hebben, resteert slechts een verschil van 1 g/km tussen WLTP- en NEDC-benzineauto's en 5 g/km tussen dieselauto's in het macrobeeld voor augustus 2018 over de volledige range van voertuiggroottes.



Figuur SN-10: Verloop van de maandelijks gemiddelde voertuigkenmerken van WLTP- en NEDC-auto's in de registraties van de RDW. Het betreft het voertuiggewicht (links), het motorvermogen (midden), en de catalogusprijs (exclusief BPM, rechts).

Op individueel voertuigniveau zal de introductie van de WLTP een verandering brengen. In de NEDC-methode kreeg binnen één model een vrij grote groep auto's één en dezelfde (lage) CO_2-waarde. Deze flexibiliteit is met de WLTP verdwenen en ieder individueel voertuig krijgt een eigen WLTP CO_2-waarde.

Met de omzetting van deze waarde naar een NEDC[WLTP] CO_2-waarde komt een beperkte variatie terug voor voertuigen die voorheen dezelfde waarde hadden. Een deel van de flexibiliteit in de NEDC[old] CO_2 waarde is daarmee verdwenen en hogere NEDC[WLTP] waarden voor individuele voertuigen zijn te verwachten.



Figuur SN-11: Gegeven een verschil in de WLTP CO_2-waarde van individuele voertuigen onder dezelfde typekeuring, variant en uitvoering, is er ook een verschil in NEDC[WLTP] CO_2 waarde.

Slotopmerking

Om aan de Europese CO_2-normen van 95 g/km te voldoen, zal de gemiddelde nieuwe auto in Europa tussen nu en 2021 nog 20-25% zuiniger moeten worden. Ten opzichte van het Nederlandse niveau is dat zo'n 15%. Dat 'gat' kan alleen worden overbrugd met WLTP-auto's, omdat na afloop van de restantvoorraadregeling geen NEDC-auto's meer mogen worden verkocht. Het is opvallend dat de recent geïntroduceerde WLTP-auto's niet waarneembaar zuiniger zijn dan hun NEDC-voorgangers, terwijl auto's met een geheel vernieuwde typegoedkeuring normaal gesproken zuiniger waren dan hun voorganger en vervolgens minimaal enkele jaren op de markt waren. Er zijn recent veelvuldig berichten verschenen dat de autofabrikanten nog op grote schaal testen uitvoeren om nieuwe WLTP en RDE typegoedkeuringen te verkrijgen. Weldra zullen op grote schaal nieuwe typegoedkeuringen worden afgegeven met lagere NEDC[WLTP] CO_2-waarden (2019-2020) en veel lagere WLTP CO_2-waarden (2020-2021). Dit betekent dat de WLTP-auto's die tot op heden werden geleverd een "tussenronde" vormen: een eerste tranche van WLTP-typegoedkeuringen voor auto's die slechts kort op de markt zullen zijn. Tevens wijzen de grote verschillen tussen fabrikanten (zie ook Figuur SN-8) er op dat de fabrikanten ieder op een eigen manier de WLTP nog aan het "inregelen" zijn. Het valt niet uit te sluiten dat enige stabiliteit in het systeem van CO_2-waarden pas in of na 2021 terugkeert.

Summary

The CO_2 emission of passenger cars and light duty commercial vehicles in Europe has to be determined according to official European legislation. In a transition period that started as of 1st of September 2017, the old NEDC method is being replaced by WLTP, the new method to determine the CO_2 emissions. The transition should be completed by 2019, some run out in 2020 at the latest. Changes in the CO_2 values will have an impact on – among others - the European CO_2 standards and the purchase tax on passenger cars in The Netherlands.

TNO has been asked to evaluate the changes of the CO_2 values of new passenger cars caused by the WLTP introduction. In phase 1 of the project the complexity of the transition from NEDC to WLTP has been explained[2]. In the current report the results of phase 2 will be presented: the first quantitative analyses on datasets with reference date 1st of September 2018. On the reference date insufficient information was available to perform the evaluation to its full extend and to establish results representative for the development of CO_2 values related to WLTP introduction. The data availability is expected to increase significantly over the next few months. In phase 3 (due in May 2019) a more comprehensive analyses will be presented.

The analyses in phase 2 have been based on data sources obtained from the car importers, members of the association RAI-Vereniging, and RDW. The focus was on the difference (delta) between CO_2 values determined according to the former NEDC method (NEDC cars with NEDC[old] CO_2 values) and CO_2 values derived according to the new WLTP method (WLTP cars with NEDC[WLTP] CO_2 values). This comparison only makes sense if the selected NEDC car is as much as possible equivalent to the new WLTP car. The selection of the equivalent NEDC car was done by the car importers themselves in their dataset. The match of WLTP and NEDC cars in the RDW datasets is based on vehicle characteristics. The datasets available allow to do the analyses on an overall macro level – the development of the average CO_2 values of all new WLTP cars and all new NEDC cars registered - and on a 1-on-1 comparison – the comparison of CO_2 values of a new WLTP car and the former NEDC car of same brand, model and version.

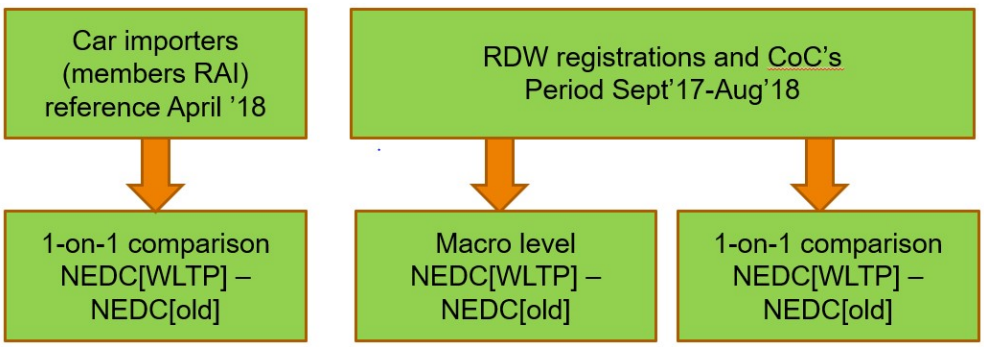


Figure S-1: Overview of the phase 2 datasets used for the comparison of NEDC CO_2 values of WLTP and NEDC cars.

[2] https://www.rijksoverheid.nl/documenten/kamerstukken/2018/07/05/onderzoek-tno-naar-aspecten-van-de-nedc-wltp-overgang-in-relatie-tot-co2-waarden-van-personenauto's

Main results

The 1-on-1 comparisons on both the RDW and RAI datasets indicate a 11-12 g/km difference between the CO_2 value of a WLTP car and its equivalent former NEDC car. In order to derive an outcome that's as much as possible representative of the car market in The Netherlands, the results are calculated by weighing the individual differences based on the share of the NEDC car in the total vehicle sales in the past 12 months.

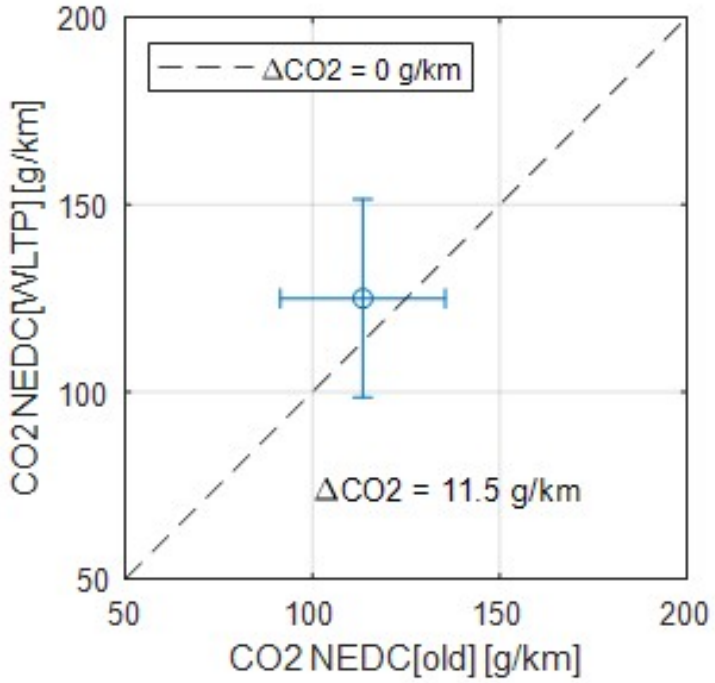


Figure S-2: The average difference and its standard deviation between NEDC[WLTP] and NEDC[old] CO_2 values in the 1-on-1 comparison based on the RDW dataset. The standard deviation is considerably higher than the calculated average result.

On the macro level, the analyses of the RDW dataset show a strong decrease in the course of 2018 of the difference between the average NEDC[WLTP] and average NEDC[old] CO_2 values (see figure S-3). Simultaneously the number of registration increased. In August 2018, the difference was 9 g/km.

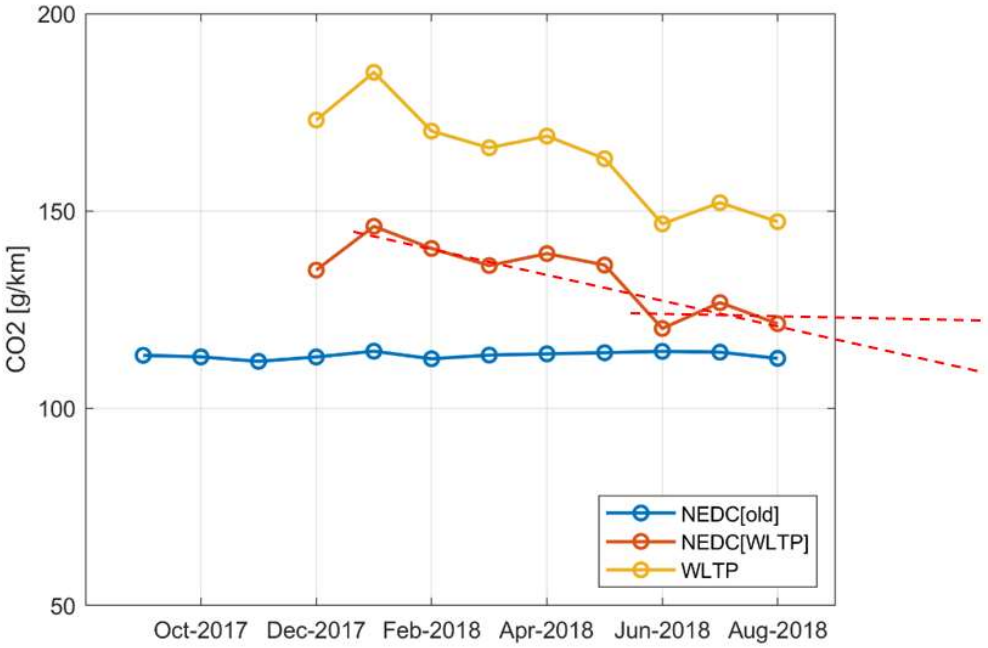


Figure S-3: Development of the monthly average NEDC[WLTP] and NEDC[old] CO_2 values in the RDW car registrations. The dashed lines reflect the uncertainty in the expected trend in the next few months. The monthly average WLTP CO_2 value is derived by matching the registrations to CoC's delivered by RDW.

The average NEDC[old] CO_2 value is expected to drop slightly in the coming months. As of 1st September 2018 only NEDC cars can be registered in The Netherlands if the cars have been produced, are present in the EU and have been registered as end-of-series stock at the RDW. In total 90,000 vehicles have been signed up, a volume comparable to the car sales in the last 3-4 months of a normal year. The CO_2 value of the end-of-series stock is on average over 3 g/km lower than the average CO_2 value of NEDC cars sold last year. The cars don't necessarily have to be sold in The Netherlands, they can also be sold in other countries. In addition to the end-of-series stock new NEDC cars registered in other countries can be imported as well.

Table S-1: Average NEDC[old] CO_2 value of the cars registered as end-of-series stock in The Netherlands compared to the CO_2 value of all cars sold in The Netherlands in the period September 2017 – August 2018. Source: RDW, specific one-off data delivery to this project.

NEDC[old] (g/km)	NEDC cars registered Sept.'17 – Aug.'18	NEDC cars signed up for end-of-series stock
Petrol	113,7	108,1
Diesel	112,1	130,8
Total	113,5	110,0

It's hard to predict the development of the average NEDC[WLTP] CO_2 values for the near future, given the fact that the development on the macro level in the last three months deviates from the trend in the first months of 2018 (see Figure S-3). The uncertainty is confirmed by the fact that the development on the macro level deviates from the 1-on-1 comparisons. None of the approaches is considered to be fully representative.

The macro level on the one hand is hampered by the limited number of WLTP car registrations: in August 2018 merely 17% of all car registrations concerned WLTP cars (see Figure S-4). It's likely WLTP cars have been brought to the market in particular if the former NEDC car was close to WLTP compliance. And also the smaller and lighter cars seem to be under-represented in the WLTP registrations (see Figure S-10).

On the other hand in the 1-on-1 comparisons important brands and models are missing. The RAI dataset is comprehensive but not covering the full car market. The 1-on-1 comparison of the RDW dataset could only be performed on a limited number of car models.

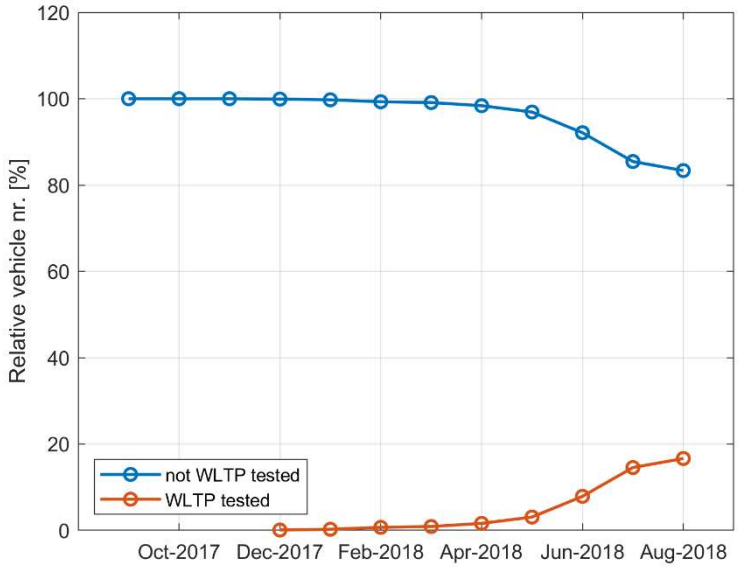


Figure S-4: Monthly share of WLTP cars in the new registrations at RDW in the period September 2017 – August 2018. In August the share was 17%.

Other elements that considerably add to the uncertainty in the future development of the average NEDC[WLTP] CO_2 values on the macro level:

- The standard deviations of almost all results are comparable to or larger than the observed effect (see also Figure S-2).
- The large spread among car brands, indicating that manufacturers all have their own interpretation and strategy in the NEDC – WLTP transition (see Figure S-5).
- The elements determining the differences between WLTP and the former NEDC method can only be quantified, and thus explained, to a limited extend (see Figure S-6).

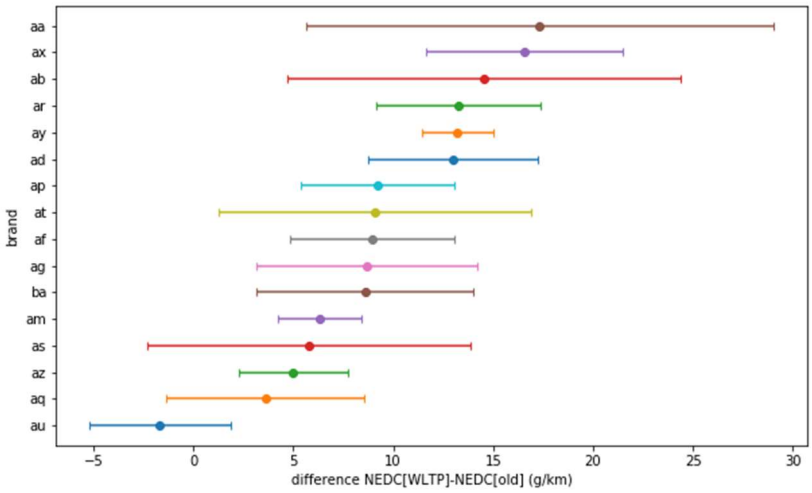


Figure S-5: The average difference of and standard deviation in NEDC[WLTP] and NEDC[old] CO_2 values of the brands included in the RAI dataset. The brands have been anonymized.

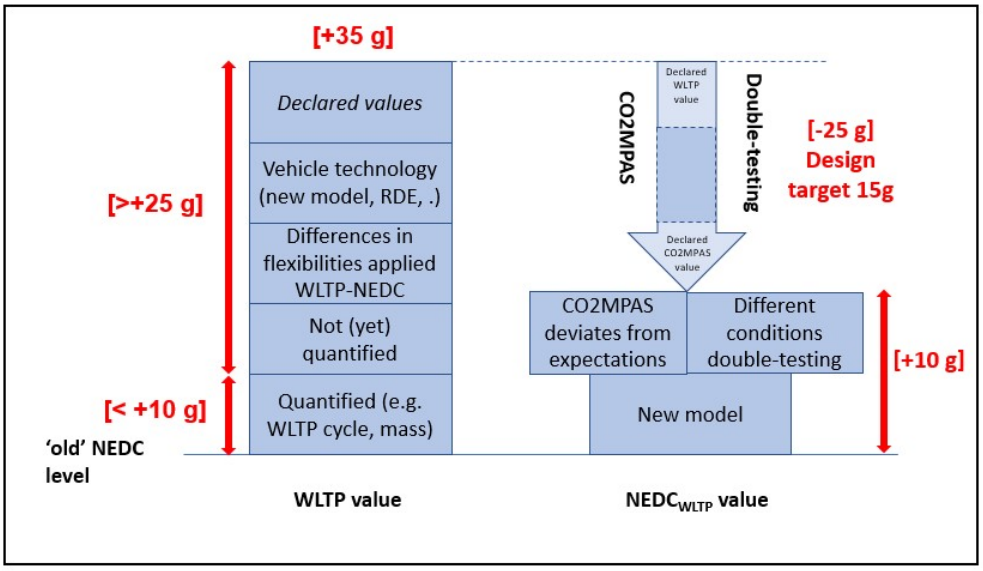


Figure S-6: Schematic overview of elements determining the difference between WLTP and the former NEDC method. The sizes of the blocks are no indication of the effects. The elements can only be quantified to a limited extend. The figure is an update of the figure presented in the phase 1 report: also in the conversion of WLTP CO_2 values to NEDC[WLTP] CO_2 values declared values can be used.

Specific results and consideration

No indications have been found that the difference between the NEDC[WLTP] and NEDC[old] CO_2 value is somehow related to the CO_2 value of the car (see Figure S-7) or its vehicle segment (see Figure S-8). The best fit is an absolute difference of 10-12 g/km, irrespective of the size of the vehicle. And again, the

spread in individual differences is larger than the magnitude of the observed average difference.

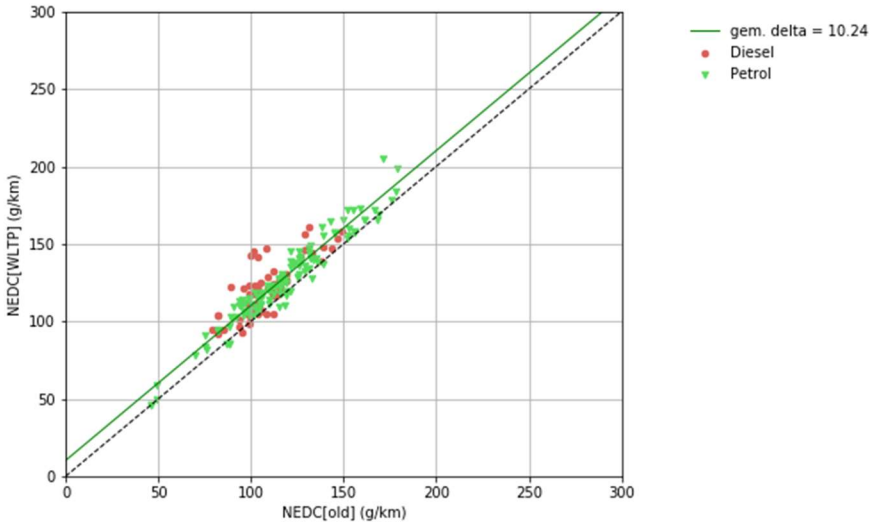


Figure S-7: NEDC[WLTP] CO_2 values plotted against NEDC[old] CO_2 values for those cars in the RAI dataset that already had a CoC available. For this dataset an (absolute) difference of slightly over 10 g.km gives the best fit.

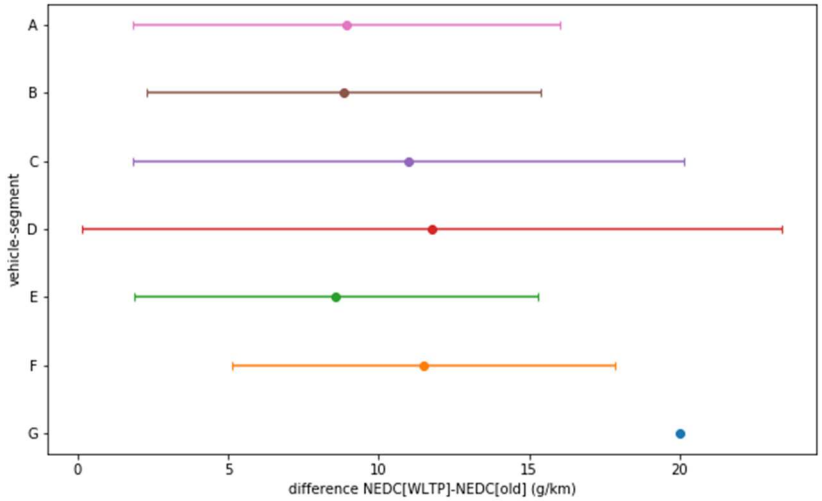


Figure S-8: Average difference and standard deviation between NEDC[WLTP] CO_2 values and NEDC[old] CO_2 values for different vehicle segments (A to G), for those cars in the RAI dataset that already had a CoC available.

A significant difference between petrol and diesel cars can be observed.
For diesel cars the difference in average NEDC[WLTP] and NEDC[old] CO_2 value is approximately 4 g/km higher than for petrol cars. This is, among others, due to the additional technological efforts needed for diesel cars to comply with both WLTP and the simultaneously introduced RDE legislation and the fact that the first generation of WLTP diesel cars was bigger and heavier.

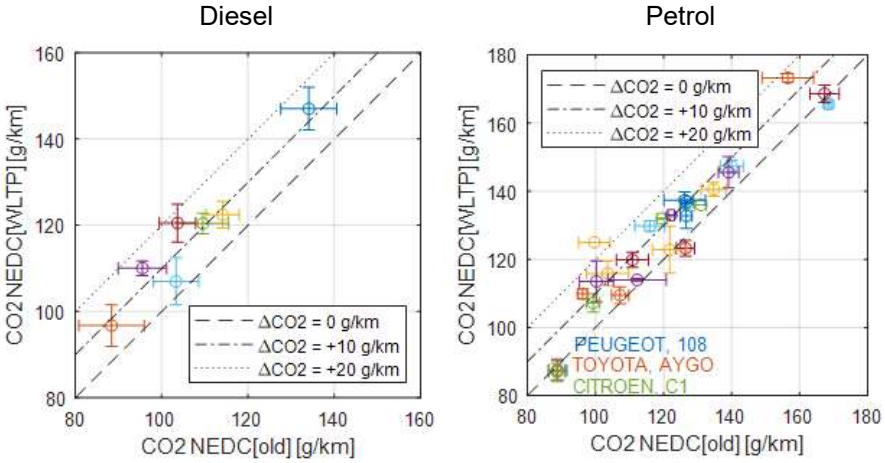


Figure S-9: Average NEDC[WLTP] CO_2 values plotted against NEDC[old] CO_2 values, including the observed spread in values, for specific diesel (left) and petrol (right) cars from the RDW dataset for which a 1-on-1 comparison could be made.

In this study WLTP cars have been carefully linked to their most equivalent former NEDC model. Nevertheless, the WLTP car is a new model that will deviate from the former NEDC car. The first WLTP cars registered in The Netherlands were much heavier, more expensive and more powerful. Since May 2018 the vehicle characteristics of the WLTP cars converge towards the average NEDC car, but a difference still remains (see figure S-10). In general heavier and more powerful cars have higher CO_2 values. And indeed, the development of the differences in vehicle characteristics between WLTP and NEDC cars show a trend similar to the development of the difference in CO_2 values on the macro level. If the remaining differences in vehicle characteristics, mass and power, are corrected for by linear regression, only a 1 g/km difference for petrol cars and a 5 g/km difference for diesel cars would remain in CO_2 values on the macro level in August 2018 over the full range of vehicle sizes.

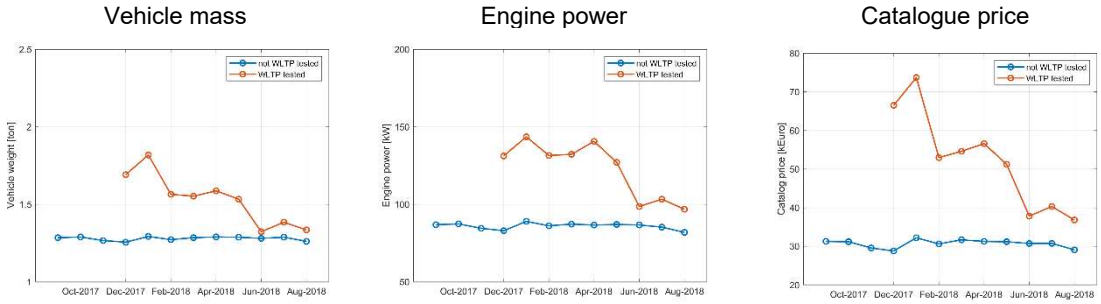


Figure S-10: Development of monthly average vehicle characteristics of WLTP and NEDC cars, based on data of RDW registrations. The characteristics considered are price (BPM purchase tax excluded), mass and engine power.

The introduction of WLTP will bring a chance to the CO_2 values at the level of individual vehicles, Under NEDC a substantially large group of vehicles of the same model had one and the same (low) CO_2 value. This flexibility will disappear under WLTP. Every vehicle will receive a specific CO_2 value.
The conversion of the WLTP CO_2 value to NEDC[WLTP] CO_2 values will bring different CO_2 values to cars that used to have the same CO_2 value. This flexibility in

NEDC[old] CO_2 value has been partially removed and slightly higher NEDC[WLTP] values for individual vehicles can be expected.

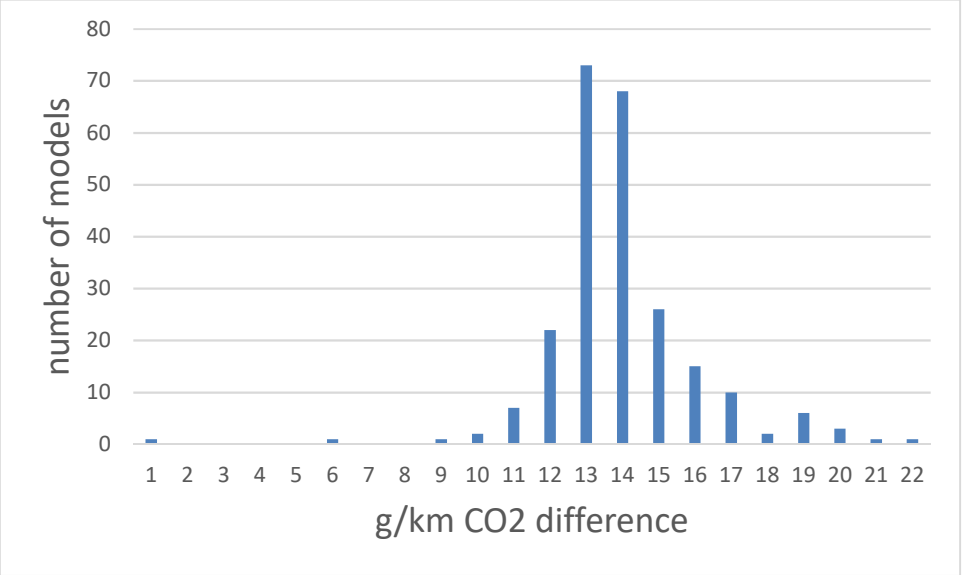


Figure S-11: The fact that WLTP CO_2 values will differ for individual vehicles of the same type-approval, model, variant and version, will also bring differences in NEDC[WLTP] CO_2 values.

Final remarks

In order to comply with the European CO_2 standards of 95 g/km the average CO_2 value of new cars to be sold in Europe will have to decrease by 20-25% between 2018 and 2021. At a national level in The Netherlands the decrease has to be approximately 15%. To close the gap the improvement will have to come from WLTP cars, as no new NEDC cars can be registered, apart from the limited number in the end-of-series stock. In this respect it's remarkable that no fuel efficiency improvements have been observed between the newly introduced WLTP cars and their predecessors, while in general (re)new(ed) models used to be more fuel efficient than their predecessor and used to be on the market for at least a couple of years. It has been widely reported that car manufacturers are currently still performing numerous tests to apply for new WLTP and RDE type-approvals. Before long a large amount of new type-approvals will be issued with lower NEDC[WLTP] CO_2 values (2019-2020) and much lower WLTP CO_2 values. This means the type-approvals that have been issued so far are part of an intermediate round: a first batch of WLTP type-approvals that will be on the market for only a limited period of time. Every car manufacturer seems to have its own approach and strategy to cope with the introduction of the WLTP (see also Figure S-8). It can be expected that the stability in CO_2 values will only return no earlier than 2021.

Contents

1 Introduction

The CO_2 emission of passenger cars and light duty commercial vehicles in Europe has to be determined according to official European legislation. In a transition period that started as of 1st of September 2017, the old NEDC method is being replaced by WLTP. The WLTP is the new method to determine the CO_2 emissions. The transition should be completed by 2019 with some run out in 2020 the latest. Changes in the CO_2 values will have an impact on – among others - the European CO_2 standards and the purchase tax on passenger cars in The Netherlands.

TNO has been asked to evaluate the changes of the CO_2 values of new passenger cars caused by the WLTP introduction. In phase 1 of the project the complexity of the transition from NEDC to WLTP has been explained[3]. In the current report the results of phase 2 are presented: the first quantitative analyses on datasets with reference date 1st of September 2018. From the 1st of September 2018, in general all vehicles newly registered in the European Union have to be type-approved according to the WLTP. Only vehicles, that were already in stock before the 1st of September 2018, and have been registered for the end-of-series stock before mid-September 2018, are still allowed to be newly registered with an NEDC type-approval. So given this status, early September, makes it possible to have an initial impression on the transition from NEDC to WLTP, for vehicles entering the Netherlands. On the reference date insufficient information was available to perform the evaluation to its full extend and to establish results representative for the development of CO_2 values related to WLTP introduction. The fraction of WLTP vehicles registered is growing rapidly, but in August 2018 still over 80% of vehicles registered were NEDC type-approved. The data availability is expected to increase significantly over the next few months. In phase 3 (due in May 2019) a more comprehensive analyses will be presented.

1.1 Definitions

Throughout the report CO_2 values of vehicles type-approved according to the WLTP will be compared to vehicles type-approved according to the NEDC. The following definitions and abbreviations will be used:

Vehicles

- *NEDC car*: passenger car tested according to the NEDC type approval procedure.
- *WLTP car*: passenger car tested according to the WLTP type approval procedure.

CO_2 values

- NEDC CO_2 value or *NEDC[old]* CO_2 value: CO_2 value of a NEDC car, the selected NEDC car should be 'the NEDC car best comparable to the new WLTP car'.
- WLTP CO_2 value: WLTP CO_2 value of a WLTP car.

[3] https://www.rijksoverheid.nl/documenten/kamerstukken/2018/07/05/onderzoek-tno-naar-aspecten-van-de-nedc-wltp-overgang-in-relatie-tot-co2-waarden-van-personenauto's

- *NEDC[WLTP]* CO2 value: NEDC CO_2 value of a WLTP car derived from its WLTP CO_2 value by either the use of the CO2MPAS tool or by double-testing (an NEDC test performed with a WLTP car).
- *Delta:* difference between NEDC[WLTP] CO_2 value and NEDC[old] CO_2 value.

Datasets

- *RAI dataset*: data delivered by the car importers in The Netherlands, members of the association RAI-Vereniging.
- *RDW dataset:* data delivered by the RDW on registrations and CoC's (Certificate of Conformity, in Dutch: CvO) of cars on the market in The Netherlands. RDW also delivered data on the end-of-series stock.

1.2 Data sources

The analyses in phase 2 have been based on data sources obtained from the car importers, members of the association RAI-Vereniging, and RDW. The focus of the analyses is on the difference (delta) between CO_2 values determined according to the former NEDC method (NEDC cars with NEDC[old] CO_2 values) and CO_2 values derived according to the new WLTP method (WLTP cars with NEDC[WLTP] CO_2 values). This comparison only makes sense if the selected NEDC car is as much as possible equivalent to the new WLTP car. The selection of the equivalent NEDC car was done by the car importers themselves in their dataset. The match of WLTP and NEDC cars in the RDW datasets is based on vehicle characteristics. The datasets available allow to do the analyses on an overall macro level (the development of the average CO_2 values of all new WLTP cars and all new NEDC cars registered) and on a 1-on-1 comparison (the comparison of CO_2 values of a new WLTP car and the former NEDC car of same brand, model and version).

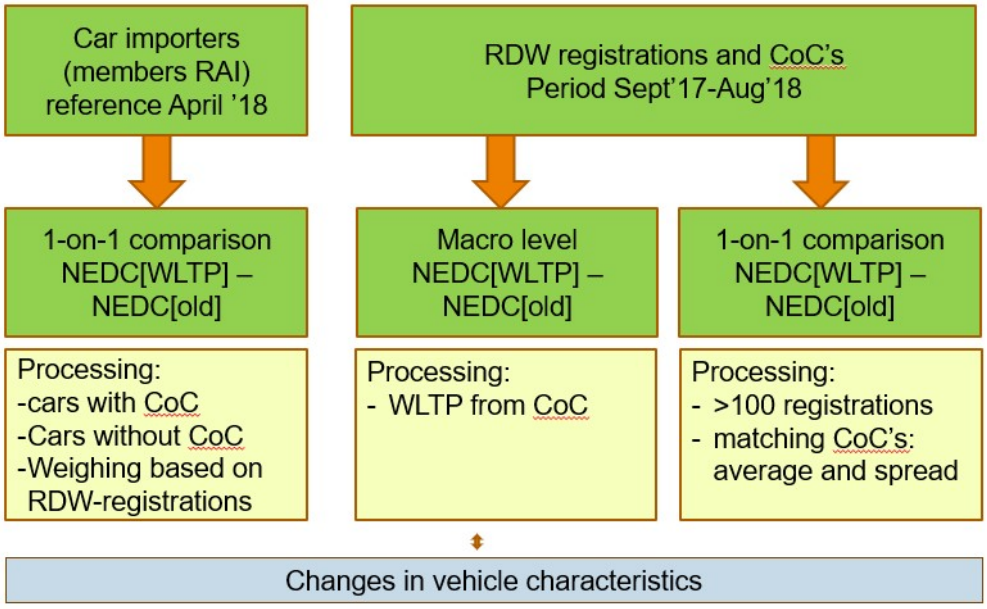


Figure 1: Overview of the phase 2 datasets used for the comparison of NEDC CO_2 values of WLTP and NEDC cars. The datasets are used to do analyses on a macro level and on 1-on-1 comparison. The main processing steps are included.

The analyses on the RAI dataset will be presented in Chapter 2. The analyses on the RDW datasets will be presented in the Chapters 3 to 6.

2 New vehicle models available

The introduction of passenger cars tested according to WLTP takes up very slowly. Even in August 2018, the last month before the general mandatory application of WLTP, less than 20% of new registrations of passenger cars had a WLTP type-approval. For this reason an additional data source from the car importers, additional to the registration data of the RDW was used.

The RAI Vereniging, the association of car importers in The Netherlands, and its members offered to make available preliminary CO_2 values of WLTP cars that will come to the Dutch market in the short term. The information on CO_2 is delivered by the car manufacturers to the car importers in advance of actual market introduction to give them the possibility to publish pricelists.

In total 26 brands delivered CO_2 values for 708 different models or variants, The data of the car importers is considered to be representative of the WLTP cars available on the market in The Netherlands: the models or variants represent 50% of the WLTP cars that have been registered up to August 2018.

2.1 Overview of data delivered by the car importers

2.1.1 2 datasets

The car importers delivered the following datasets:

- "NEDC official"
  This set consists of data on WLTP cars that already have a CoC and therefor have an official individual car specific CO_2 value. The car importers mainly delivered the NEDC CO_2 value (201 cases). Only in 29 cases besides the NEDC CO_2 value also the WLTP CO_2 value was delivered; this is an insufficient basis to perform analysis on the WLTP values.
- "NEDC preliminary"
  This set consists of data on cars that are expected to come to the Dutch market as WLTP-cars but **no** CoC is available yet. The delivered NEDC CO_2 value is considered to be the best guess by the car manufacturer of the CO_2 value of the car that finally will be produced. The car importers mainly delivered the NEDC CO_2 value (506 cases). Only in 49 cases besides the NEDC CO_2 value also the WLTP CO_2 value was delivered; this is an insufficient basis to perform analysis on the WLTP values.

Due to the different character of both datasets, the datasets have been analysed separately and the results will be presented separately.

2.1.2 Data delivered

The car importers delivered the following data of the new (WLTP-tested) version and the old (NEDC-tested) version of a specific vehicle:

- Commercial information (Brand, model, version, segment, BPM)
- Technical specifications (Fuel type, powertrain, mass in running order, tyre size, number of cylinders, transmission, maximum power)
- CO_2-values:

- For the NEDC vehicle: NEDC[old] CO_2
- For the WLTP vehicle (official or preliminary): NEDC[WLTP] CO_2 and optionally WLTP CO_2 and WLTP test mass.

2.2 Results of the dataset of the car importers in The Netherlands (RAI dataset)

If all cars included in the RAI dataset are weighted as one single entry, the average difference between NEDC[WLTP] and NEDC[old] CO_2 value in the RAI database is in the range of 7 to 10 g/km (see Table 2-1). The average delta differs slightly between the NEDC official dataset (7.5 g/km) and NEDC preliminary dataset (10.2 g/km). The standard deviation in the results is of the same magnitude as the calculated average delta.

Table 2-1 Delta NEDC[WLTP] and NEDC[old] CO_2 value in the RAI datasets

Dataset	Δ NEDC[WLTP] CO2 value - NEDC CO2 value	
	Average	Standard deviation
NEDC official	10.2 g/km	8.7 g/km
NEDC preliminary	7.5 g/km	7.8 g/km]

The datasets have also been matched with the registrations in The Netherlands in order to weigh the results with the number of vehicles sold. This provides a more representative result for the Dutch situation, as not all models are sold in significant numbers. A subset of the RDW-database (with new registrations in the Netherlands) is used. The subset contains all Euro 6 passenger cars, registered up until August 2018. The matching has been done on three common columns in both datasets: brand, model and NEDC CO_2 emissions. Since the model names exist in numerous variations in the RDW-database, making a complete match would be a study on its own. Only trivial cleansing has been performed on both datasets and therefore not all models have been matched. Table 2-2 shows the result of the matching: 16% of the registrations in the RDW dataset could be matched to entries in the RAI dataset, covering almost half of the RAI dataset.

Table 2-2 Matching results between RDW and RAI datasets as part of the weighing process of the RAI data.

	RDW	RAI
Vehicles	1725791	696
Vehicles matched	277210 (16%)	329 (48%)

As a result of the weighing process, the delta increases to 10 to 11 g/km (see Table 2-3). The standard deviation slightly decreases, but still is of the same magnitude as the calculated average delta.

Table 2-3 Delta NEDC[WLTP] and NEDC[old] CO_2 value in the RAI datasets after the weighing process

Dataset	Δ NEDC[WLTP] CO2 value - NEDC CO2 value	
	Average	Standard deviation
NEDC official – weighted	9.7 g/km	7.8 g/km
NEDC preliminary - weighted	10.7 g/km	7.2 g/km

2.2.1 Analysis of the delta

2.2.1.1 Delta diesel slightly bigger

For diesel vehicles the delta seems to be slightly larger than for petrol vehicles. In the raw datasets the delta for diesel is 3.6 g/km larger (see Figure 2-1 and Figure 2-3). The higher delta might be related to the higher vehicle mass of the WLTP diesel cars and is not necessarily a consequence of WLTP introduction (see section 2.3.2). It might also be linked to the higher spread in the data for diesel cars.
If the datasets are registrations weighted the differences increase to 8.3 g/km and 5.0 g/km (see Figure 2-2 and Figure 2-4), but the standard deviation decreases.

Dataset official:

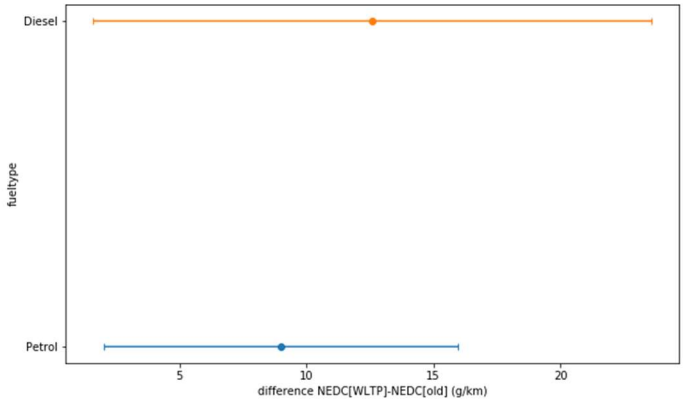


Figure 2-1 The average and spread in the difference in NEDC[WLTP] and NEDC[old] CO_2 values for petrol and diesel cars. The deviation for diesel is larger, but so is the spread. The data considered is from the RAI NEDC official dataset.

Dataset official - weighted:

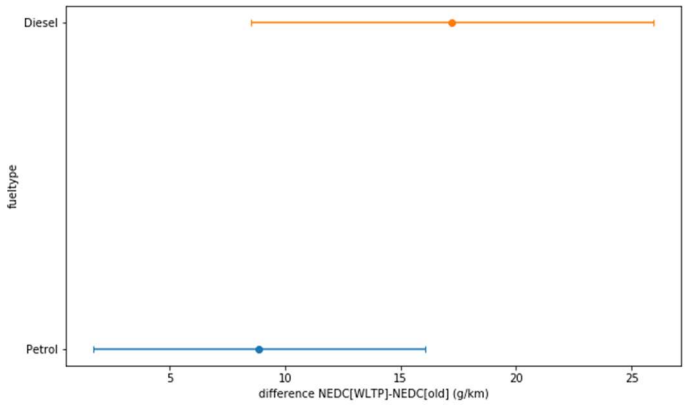


Figure 2-2 Weighing the data with NEDC vehicles sales decreases the spread, and increases the difference in NEDC[WLTP] and NEDC[old] CO_2 value for diesel vehicles.

Dataset preliminary:

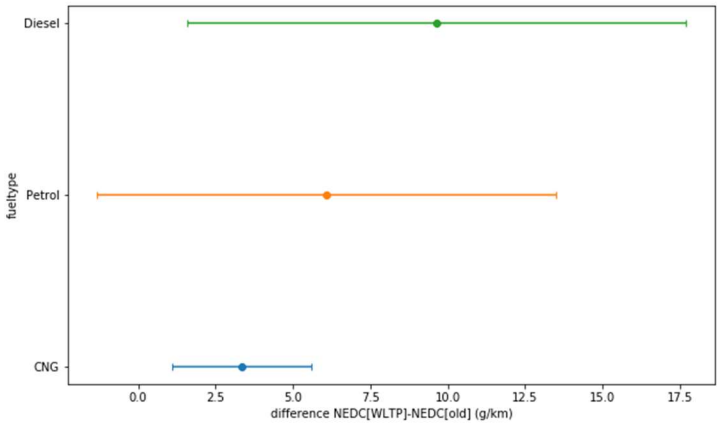


Figure 2-3 The data with preliminary estimates (RAI NEDC preliminary dataset) show smaller deviations than the vehicles with CoC available (dataset official),

Dataset preliminary – weighted:

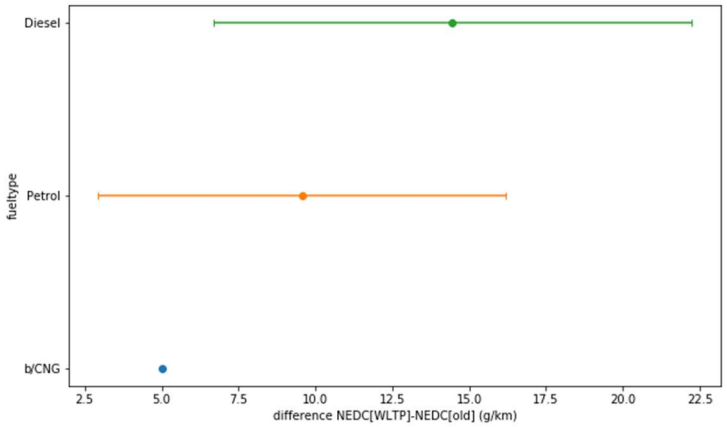


Figure 2-4 Weighing with the registration numbers shows some minor shifts, also caused by the limited data.

2.2.1.2 *No trends related to CO_2 value or car segment*

No indications have been found that the difference between the NEDC[WLTP] and NEDC[old] CO_2 value is somehow related to the CO_2 value of the car. In Figure 2-5 and Figure 2-6 the NEDC[WLTP] CO_2 values are plotted against the NEDC[old] values for both RAI datasets. The plots of NEDC[WLTP] CO_2 values against NEDC CO_2 values suggest that the delta is constant for the full range of CO_2 values (at least from 50 up to 200 gr/km). In Figure 2-7 to Figure 2-10 the delta is plotted against the car segments. The delta also seems to be constant for the full range of car segments, irrespective of the size of the vehicle.
The weighted data are considered providing a more representative result for the Dutch situation. The best fit of the weighted data is an absolute difference of 10-12

g/km. And again, the spread in individual differences is larger than the magnitude of the observed average difference.

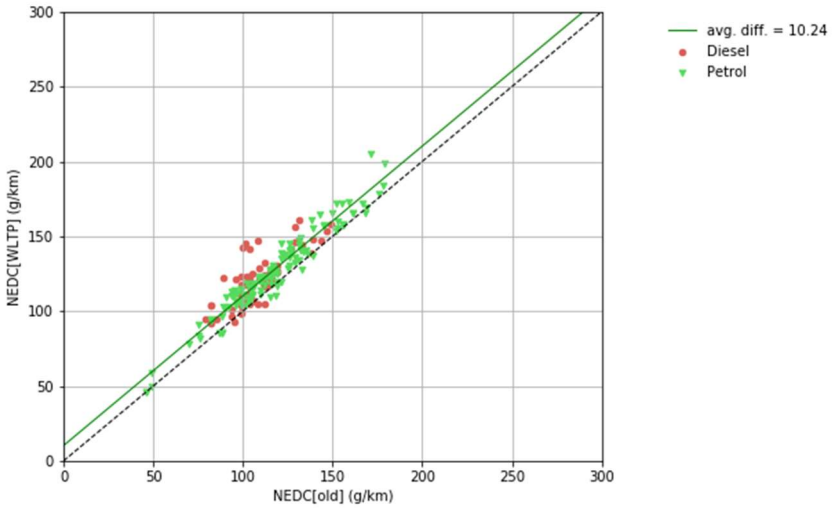


Figure 2-5 NEDC[WLTP] CO_2 values plotted against NEDC[old] CO_2 values for those cars in the RAI dataset that already had a CoC available. For this dataset an (absolute) difference of slightly over 10 g/km gives the best fit. The official data show a large spread in results, especially for diesel, with no systematic dependencies on the CO_2 value itself.

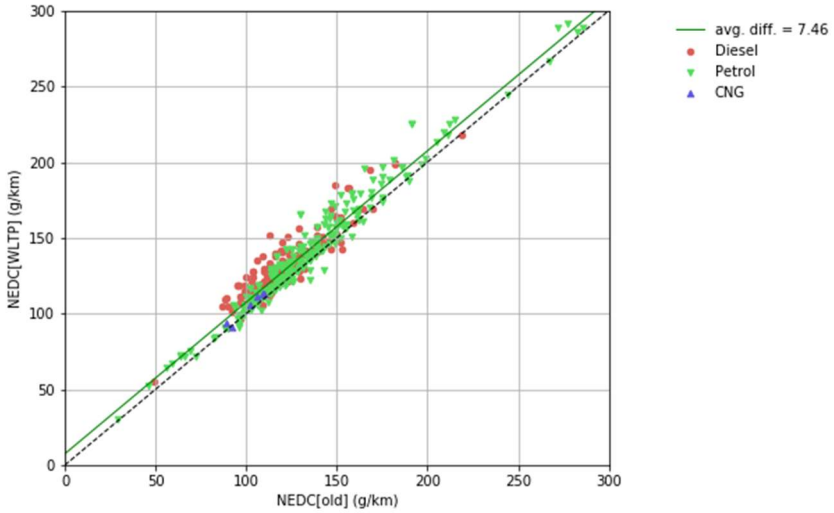


Figure 2-6 The same spread as for official numbers is found in the preliminary numbers, but the centre of gravity is substantially lower. If the datapoints are sales weighted, the average delta increases to 10.7 g/km.

Dataset official:

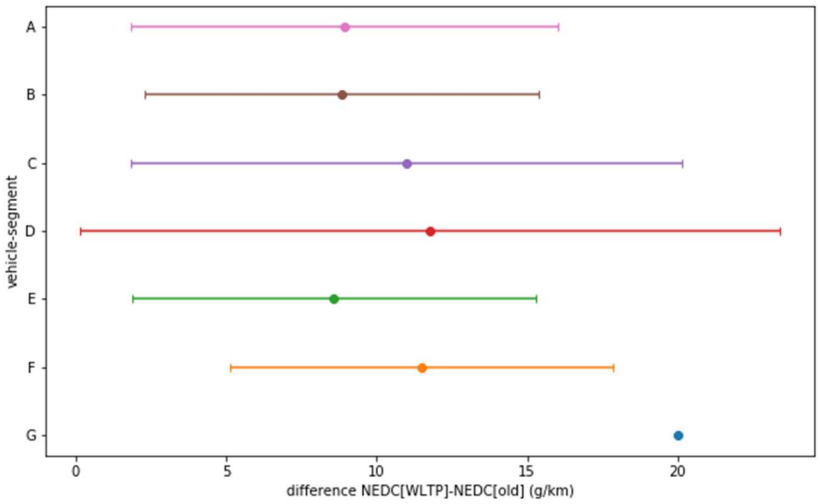


Figure 2-7 The delta between NEDC[WLTP] and NEDC[old] CO_2 values for the different car segments A to G in the dataset RAI official. With respect to the market segments A to G no trend can be uncovered in the official numbers. The standard deviation is of the same magnitude as the delta observed.

Dataset official – weighted:

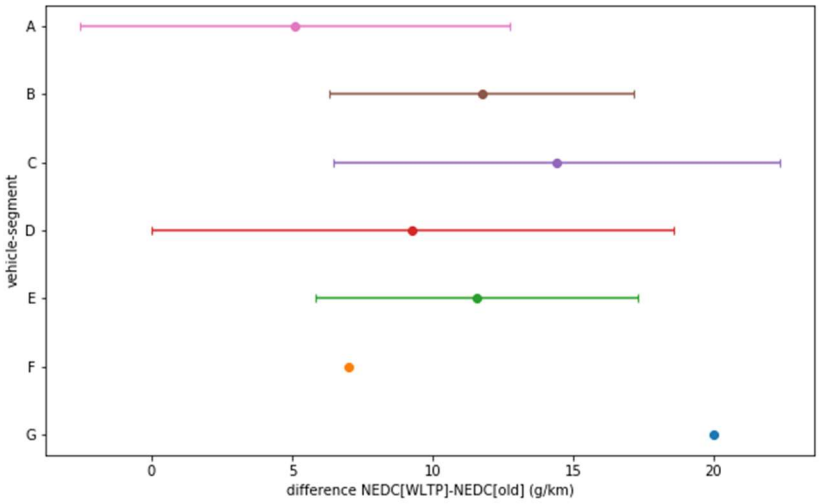


Figure 2-8 The delta between NEDC[WLTP] and NEDC[old] CO_2 values for the different car segments A to G if the data points in the dataset RAI official are sales weighted. With respect to the market segments A to G no trend can be uncovered. The standard deviation is of the same magnitude as the delta observed. The weighing of the official numbers with registrations show a dominance of a few models in the higher market segments, but no clear trend.

Dataset preliminary:

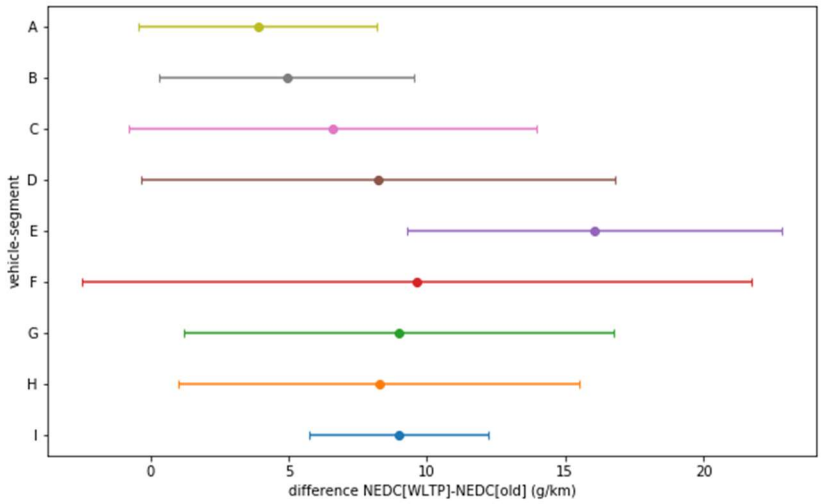


Figure 2-9 The delta between NEDC[WLTP] and NEDC[old] CO_2 values for the different car segments A to G in the dataset RAI preliminary. With respect to the market segments A to I no trend can be uncovered. The standard deviation is of the same magnitude as the delta observed.

Dataset preliminary – weighted:

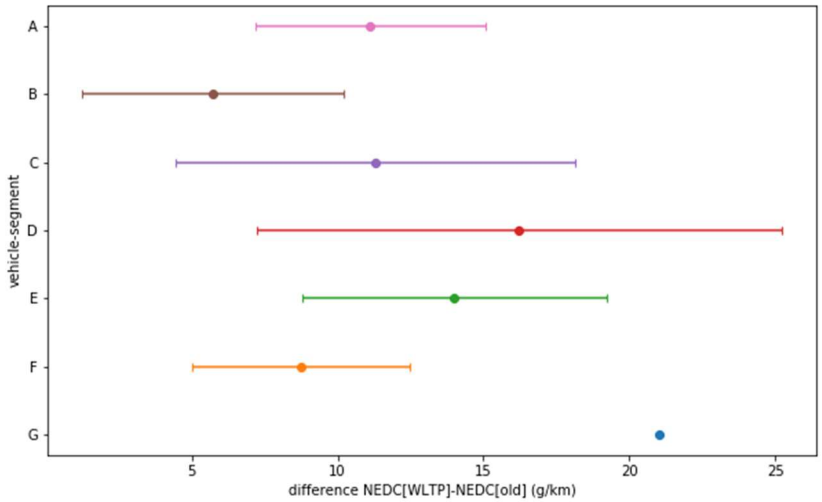


Figure 2-10 The delta between NEDC[WLTP] and NEDC[old] CO_2 values for the different car segments A to G if the data points in the dataset RAI preliminary official are sales weighted. For the segments H and I of Figure 2-9 no match could be made with the RDW registrations. The weighing of the official numbers with registrations show a dominance of a few models in the higher market segments, but no clear trend.

2.2.1.3 Large spread among car brands

The delta's between NEDC[WLTP] and NEDC[old] CO_2 values have also been analysed per car brand. This gives striking results. The differences in delta's between manufacturers are big and significant and range from small delta's (<5 g/km) to large delta's (>>15 g/km). Why these differences occur cannot be determined from the datasets delivered, nor being double checked against the RDW registrations (see chapter 3), but indicates that manufacturers all have their own interpretation and strategy in the NEDC – WLTP transition. This element will be further investigated in phase 3 of the project, due in 2nd quarter 2019.
Figure 2-11 to Figure 2-14 present the delta's per car brand for both RAI datasets ('official' and 'preliminary') and both unweighted and sales weighted results.

Dataset official:

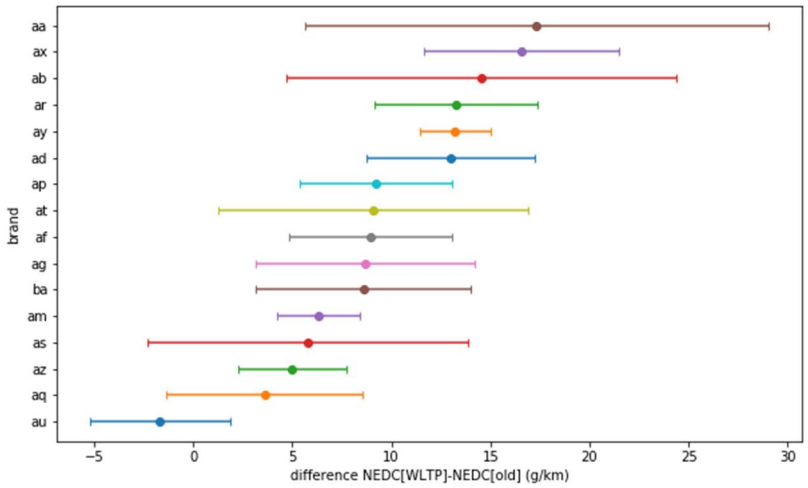


Figure 2-11 Delta's between NEDC[WLTP] and NEDC[old] CO_2 values per car brand. The brands are sorted to the average difference in the official numbers, which shows, apart from the large spread, also a large difference between manufacturers.

Dataset official – weighted:

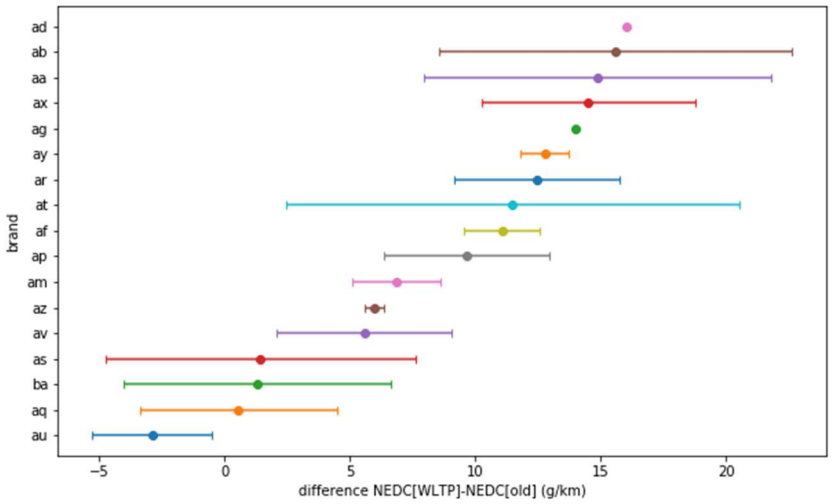


Figure 2-12 The weighing of the official numbers with registrations amplifies the differences between manufacturers and brands.

Dataset preliminary:

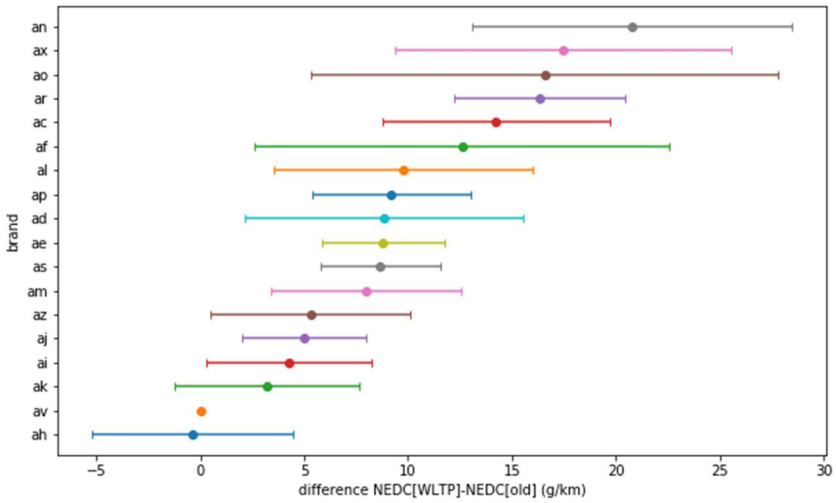


Figure 2-13 The preliminary numbers show a similar spread the difference among the brands.

Dataset preliminary – weighted:

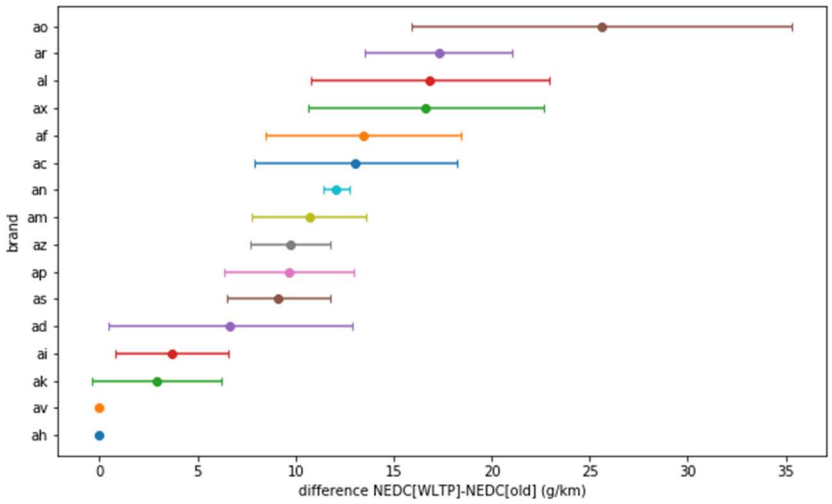


Figure 2-14 Weighing the preliminary numbers with registrations does not change the global picture, but reduces the number of relevant vehicle models.

2.3 Discussions specifically on RAI datasets

2.3.1 Standard deviation

The datasets delivered by the car importers show a large scattering, that results in a large standard deviation. The standard deviation is comparable to the average delta's presented in the previous sections. This means that the uncertainty is high and as a consequence all results presented should be taken with caution.

2.3.2 *Best comparable previous NEDC car*

The analyses performed strongly depend on the selections of the NEDC car. The NEDC car should be the previous car best comparable to the new WLTP car. The selection of the NEDC car was done by the car importers individually. This selection can only be checked indirectly by comparing some objective characteristics of the NEDC and WLTP car. For this comparison the mass of the vehicle, its engine capacity and its engine power are selected.

2.3.2.1 Vehicle mass

For petrol cars the mass of the NEDC and the WLTP car do match, with only a few outliers. For diesel cars the vehicle mass seems to be significantly higher, in particular in the lower range of vehicle masses (< 1500 kg). On average their mass is 30-40 kg higher, corresponding to 3-5 g/km higher CO2 value. This might largely explain the part of 4-6 g/km difference in delta between diesel and petrol cars (see section 2.2.1.1.). See Figure 2-15 and Figure 2-16.

Dataset official:

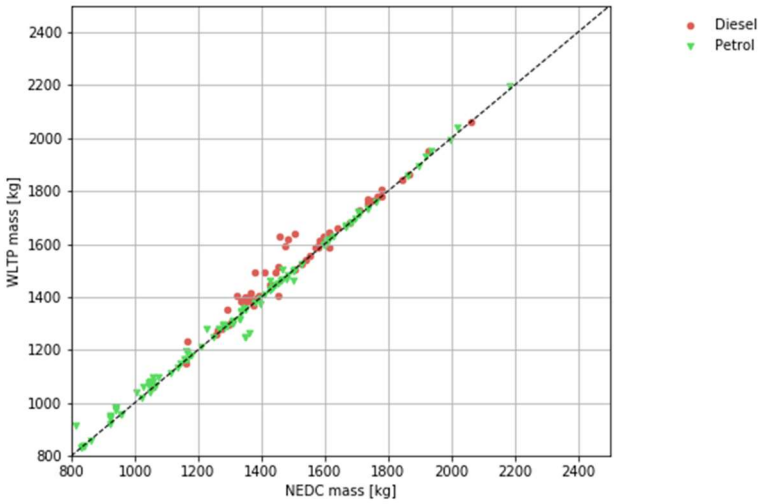


Figure 2-15 Mass of the WLTP car plotted against the mass of the previous car best comparable NEDC car according to the dataset RAI official. Mainly some diesel vehicles, in particular in the 1200-1500 kg range, have a substantial change in weight, while petrol vehicles have limited systematic change.

Dataset – preliminary:

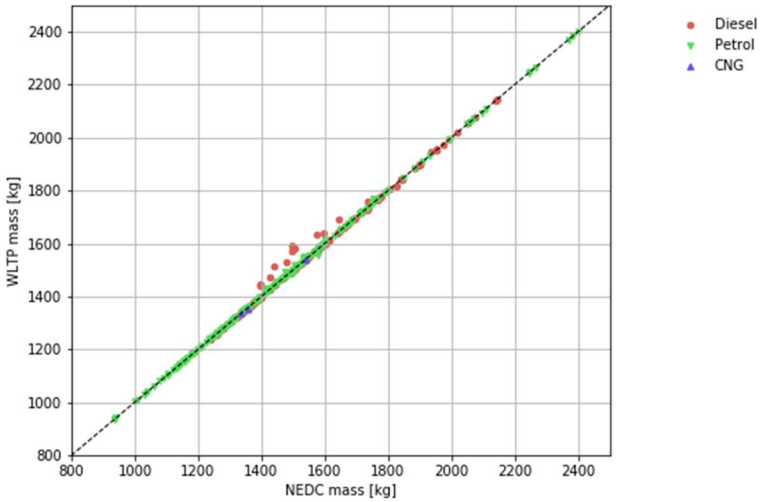


Figure 2-16 Mass of the WLTP car plotted against the mass of the previous car best comparable NEDC car according to the dataset RAI preliminary. The diesel vehicles have a change in weight, but the difference appears to be less pronounced than in Figure 2-15.

2.3.2.2 *Engine capacity and engine power*

Only with a few exceptions, in both RAI datasets no significant or systematic differences in engine capacity or engine power between the WLTP cars and the selected NEDC cars have been found.

Dataset official:

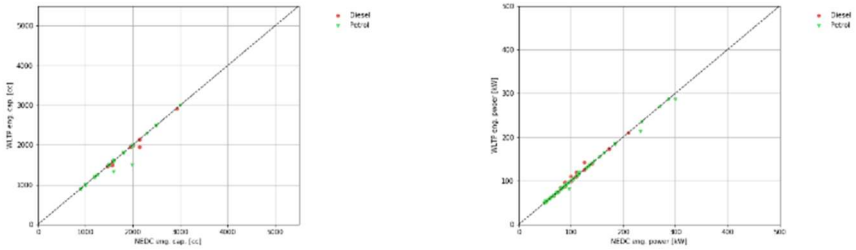


Figure 2-17 The engine capacity (left) and engine power (right) of the WLTP car plotted against the selected previous NEDC model in the dataset RAI official.

Dataset preliminary:

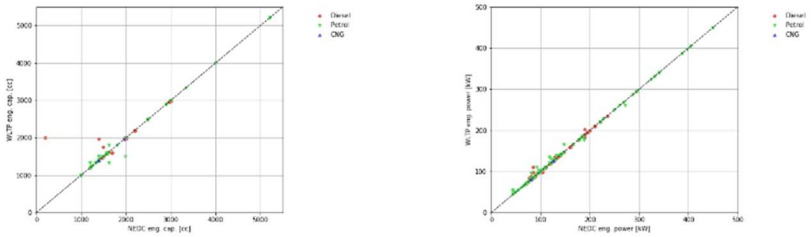


Figure 2-18 The engine capacity (left) and engine power (right) of the WLTP car plotted against the selected previous NEDC model in the dataset RAI preliminary,

3 Registrations till 1 September 2018

The RDW vehicle registration dataset is updated regularly and shows the progression in the transition from NEDC to WLTP. Given the fact that from 1 September 2018, WLTP is obliged except for end-of-series stock, the fractions of WLTP vehicles in the new registrations is still surprisingly low. In this chapter an overview is given of the new registrations of vehicles. Apart from NEDC[WLTP] CO_2 values the transition can be monitored on the basis of other data from the registrations. From the additional information it is clear that larger, more expensive vehicle models made the transition to WLTP before the other market segments. This may give the wrong impression that the transition is a larger shift in CO2 values than it will be by the end of 2018.

WLTP cars sold in the first two quarters of 2018 were heavier, more powerful, and more expensive than the NEDC cars sold in the same period. Only since May 2018 the vehicle characteristics of the WLTP cars converge towards the average NEDC car. For a more heavier and powerful vehicle it is expected that the CO_2 value is also higher. Indeed the monthly NEDC[WLTP] CO_2 follows the same trend as power and vehicle weight. It could even be concluded, that if the vehicles would have the same physical characteristics, the effect in NEDC[WLTP] CO_2 is hardly discernible.

Very notable, however, is the WLTP CO_2, which keeps a constant distant from the NEDC[WLTP] CO_2. Both for petrol and diesel there is a gap of 30 g/km, constant over time, and the change in registrations of the month. The WLTP CO_2 value seems a fixed higher value, irrespective of model or fuel.

The differences between petrol and diesel vehicles are limited. It seems WLTP diesel vehicles have limited weight increase, but a substantial increase in power. In this respect the RDW dataset deviates from the dataset of the car importers (chapter 2), that showed an increase in mass of WLTP diesel cars and no increase in engine power. The WLTP diesels sold are more expensive than the NEDC variants. As a result the BPM as a fraction of the total price of the WLTP cars sold so far remains the same with the introduction of the WLTP.

3.1 All fuels

In August 2018, less than 20% of newly registered passenger cars were WLTP type-approved (see Figure 3-2). On 1 September 2018 in total 17.000 registered passenger cars had a WLTP type-approval (see Figure 3-1).

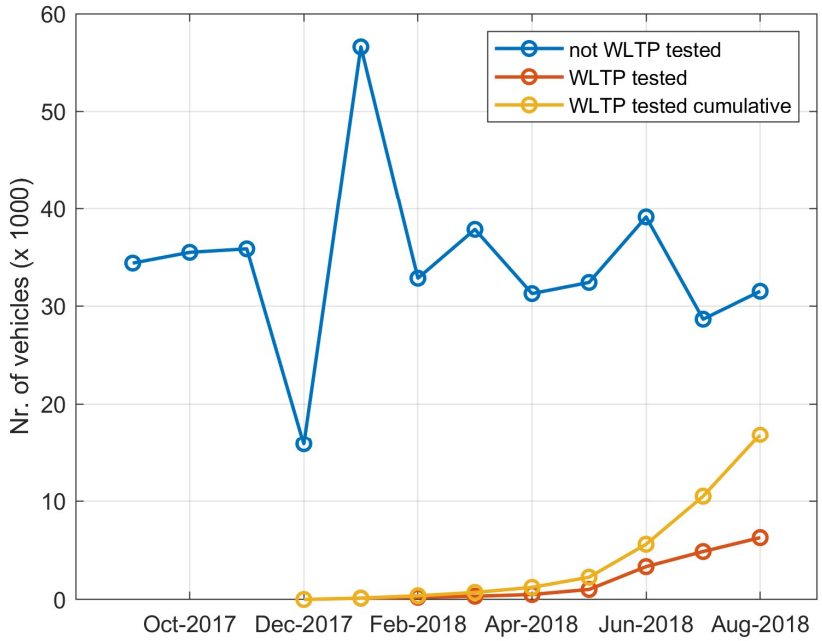


Figure 3-1 The number of vehicles in the Netherlands per registration month. Only since June 2018 the numbers of WLTP registrations are increasing to a notable fraction of the total registrations.

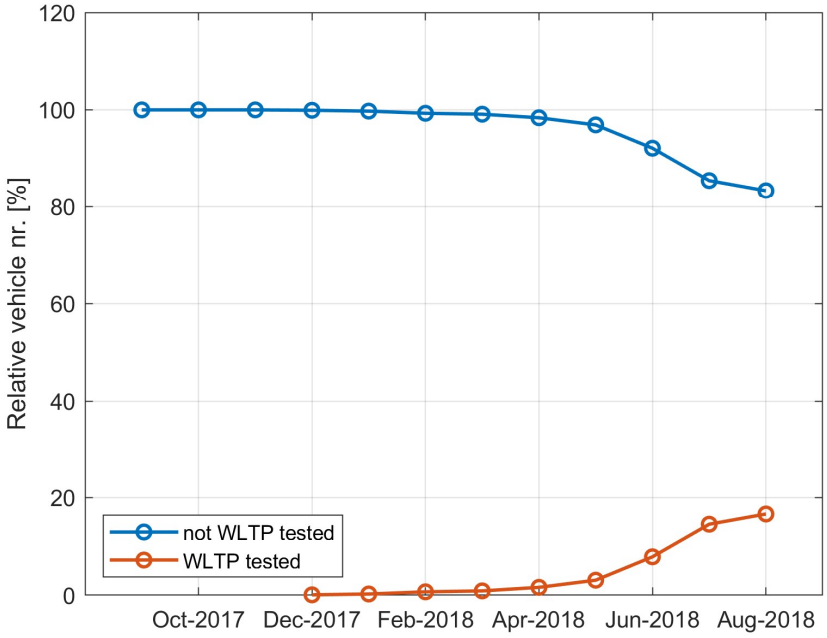


Figure 3-2 Monthly share of WLTP cars in the new registrations at RDW in the period September 2017 – August 2018. In August the share was 17%.

On the macro level, the analyses of the RDW dataset show a strong decrease in the course of 2018 of the difference between the average NEDC[WLTP] and average NEDC[old] CO_2 values (see Figure 3-3). Simultaneously the number of

registration increased. In August 2018, the difference was 9 g/km. The development indicates that the first batch of WLTP registrations mainly consisted of bigger and more expensive cars. The development in the last three months deviates from the trend in the first months of 2018. In Figure 3-3 two trendlines have been included, indicating that it is hard to predict the development in the month to come, based on the development till 1st September 2018.

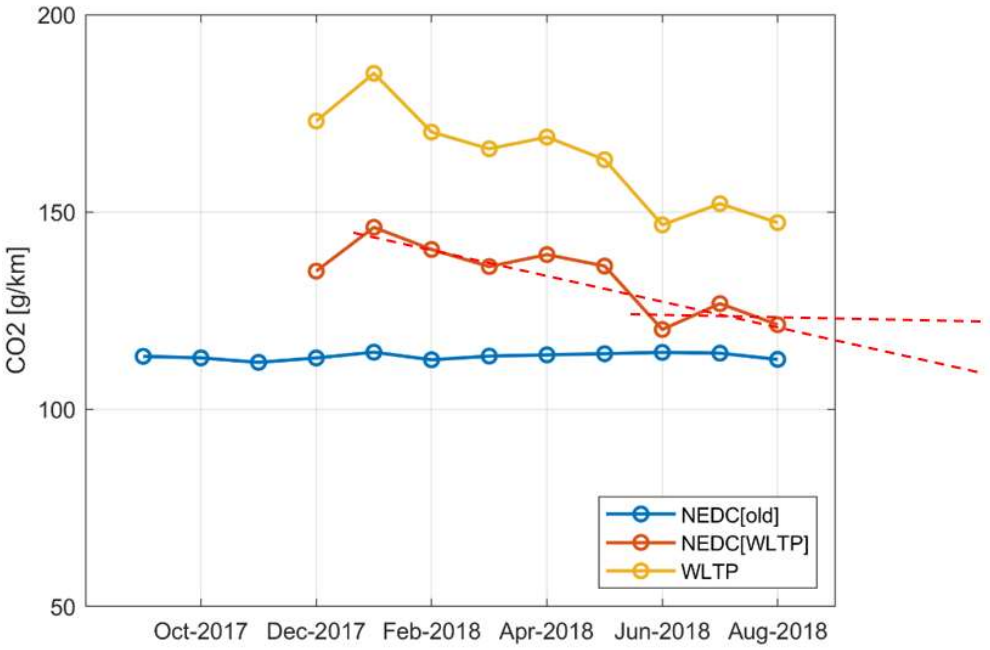


Figure 3-3 Development of the monthly average NEDC[WLTP] and NEDC[old] CO_2 values in the RDW car registrations. The dashed lines reflect the uncertainty in the expected trend in the next few months. The monthly average WLTP CO_2 value is derived by matching the registrations to CoC's delivered by RDW.

The higher monthly average NEDC[WLTP] over NEDC[old] CO_2 values directly implicates that also the BPM purchase tax of WLTP cars was higher (see Figure 3-4). At the same time WLTP cars were also more expensive than the NEDC cars sold in the same period (see Figure 3-5). The monthly average BPM as fraction of the catalogue price of the vehicles shows that the BPM of the WLTP cars registered is keeping trend with catalogue price (see Figure 3-6).

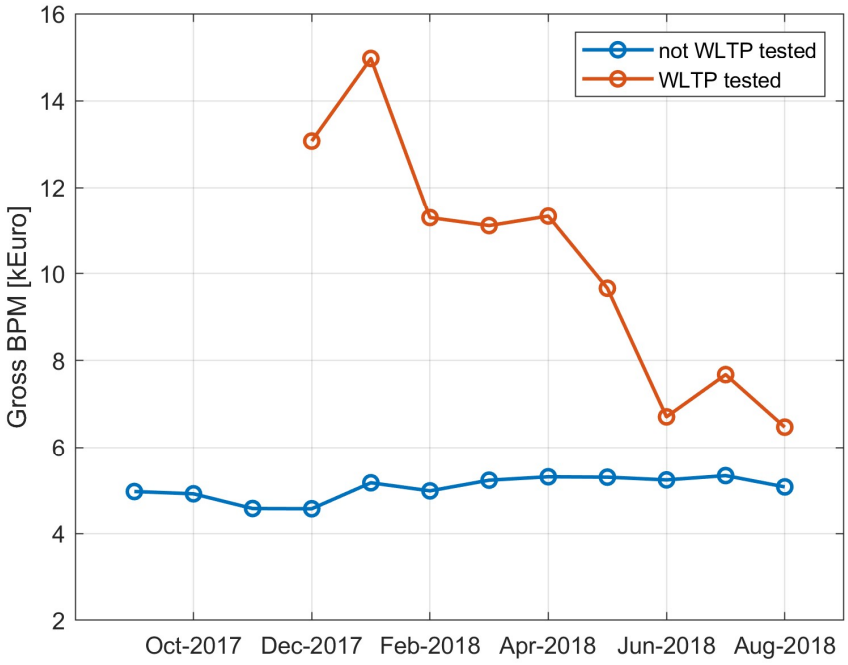


Figure 3-4 The monthly average BPM purchase tax per vehicle for both WLTP and NEDC registrations over the last year. The average BPM per car closely follows the trend of the average CO_2 value.

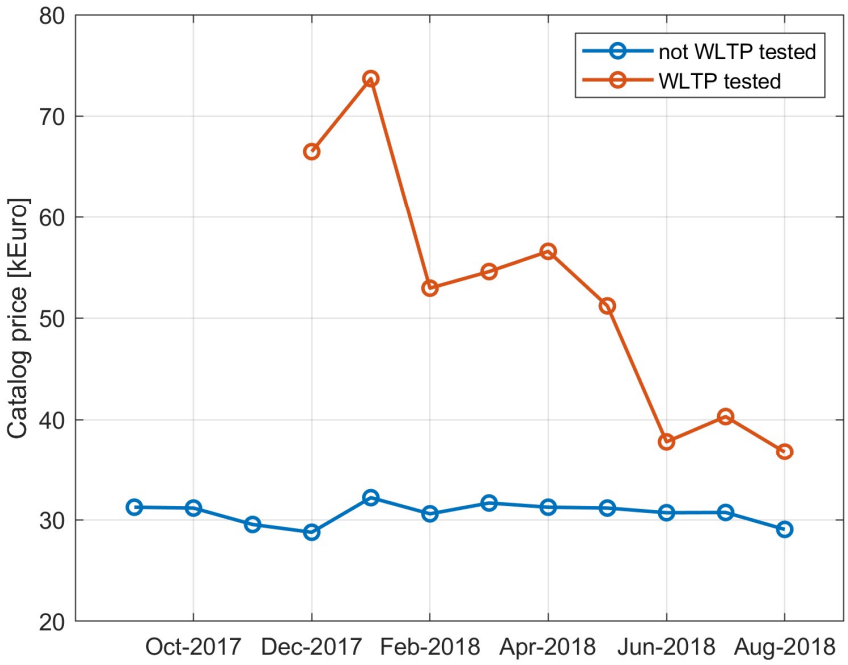


Figure 3-5 The monthly average catalogue price for both WLTP and NEDC registrations over the last year. The first WLTP cars sold in The Netherlands were more expensive than the average NEDC car.

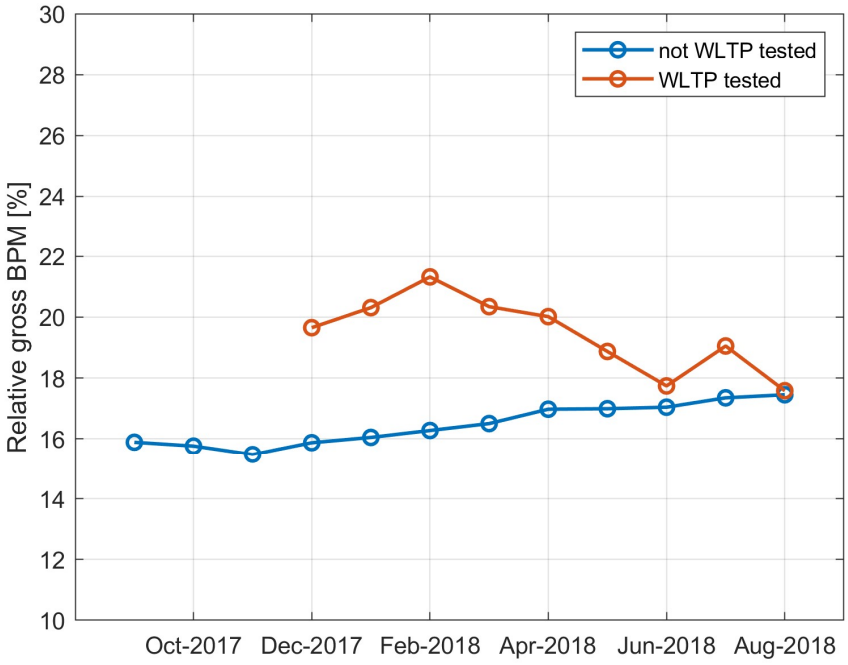


Figure 3-6 The average BPM as fraction of the catalogue price of the vehicles per month, showing that the BPM of the WLTP cars registered is keeping trend with catalogue price.

WLTP cars sold till 1st September 2018 were not only more expensive, but also heavier and more powerful than the NEDC cars sold in the same period. Only since May 2018 the vehicle characteristics mass and power of the WLTP cars converge towards the average NEDC car. See Figure 3-7 and Figure 3-9.

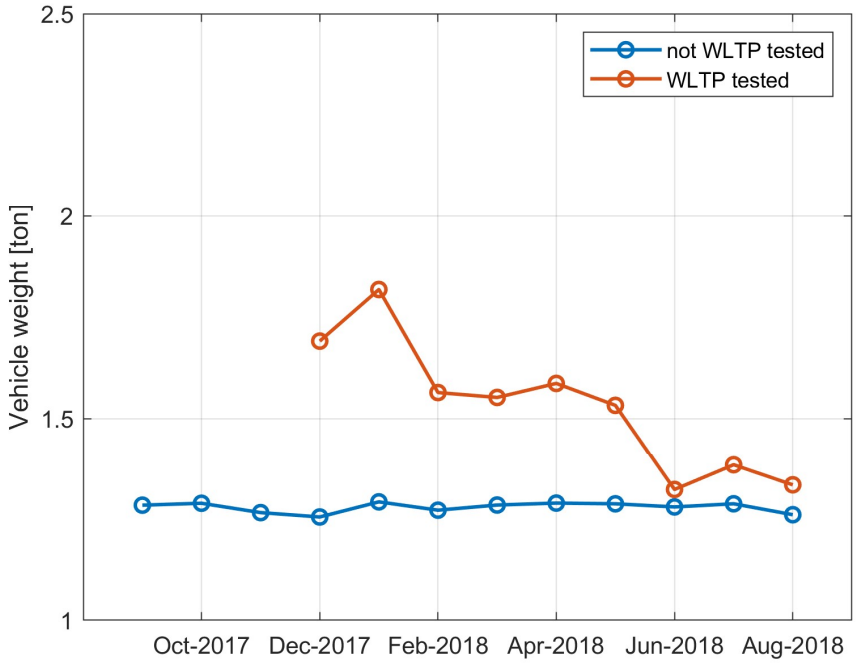


Figure 3-7 The monthly average vehicle weight of the WLTP vehicles converging towards the average NEDC vehicles.

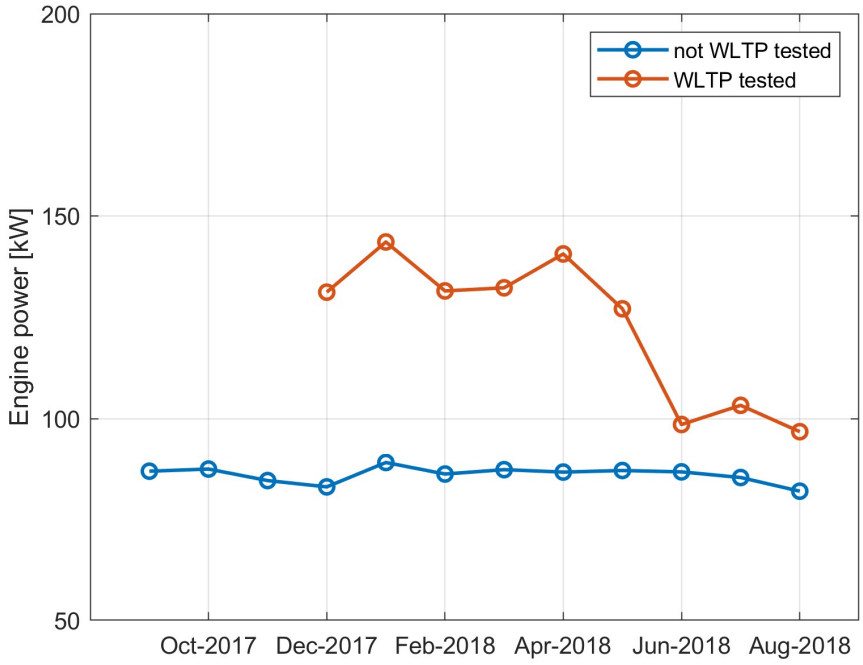


Figure 3-8 Despite the convergence since May 2018, a significant gap in engine power remains between average WLTP and NEDC car.

3.2 Petrol vehicles

In section 3.1 the analyses of registrations of all WLTP cars, their average CO_2 values and vehicle characteristics have been presented. The same analyses have been performed for the subset of petrol vehicles registered in the same period. As the car sales in The Netherlands are dominated by petrol car, the results only marginally differ from the analyses in the previous section. The results are presented in Figure 3-9 to Figure 3-16.

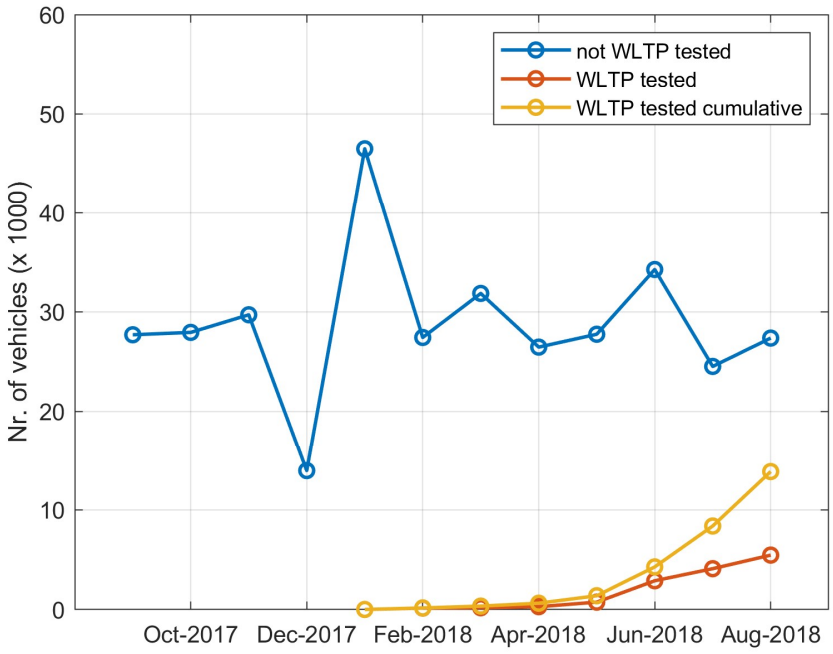


Figure 3-9 The sales of petrol WLTP vehicles is picking up quicker than of WLTP diesel vehicles.

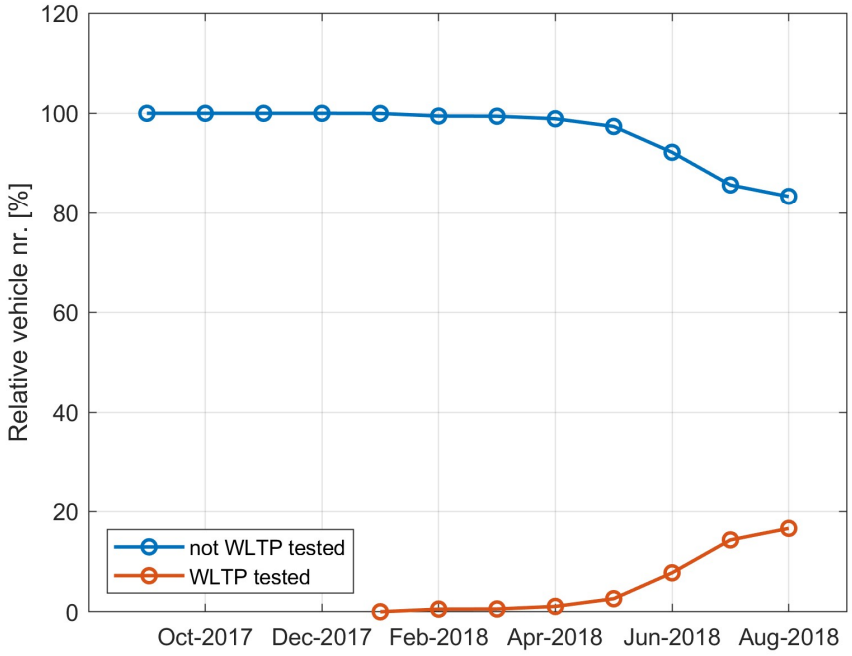


Figure 3-10 Petrol vehicles dominate the overall WLTP sales, hence the fraction of WLTP petrol vehicles in the petrol sales is similar to the overall fraction of WLTP cars.

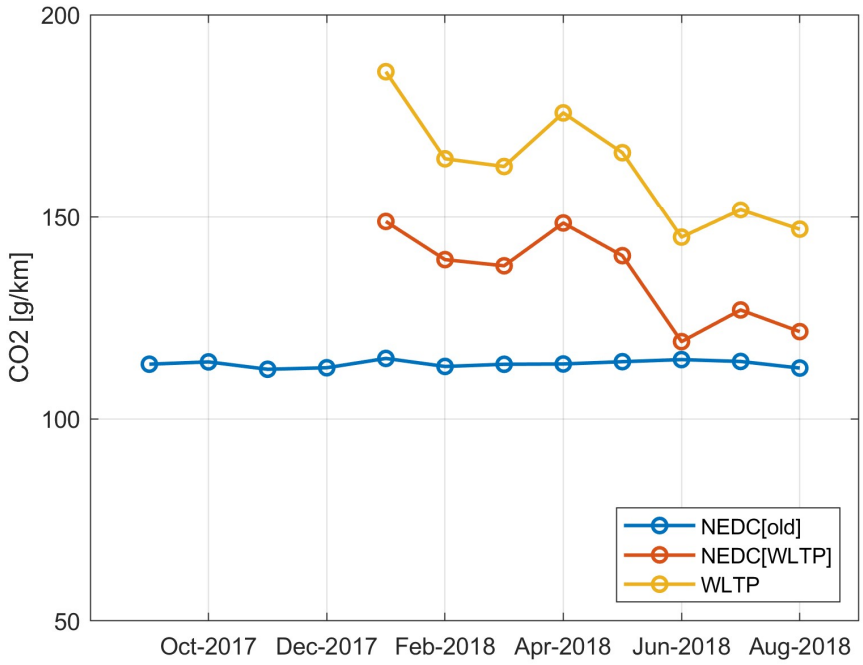


Figure 3-11 Also for petrol cars a gap of 9 g/km remains between the NEDC[WLTP] and NEDC[old] CO_2 value, but the downward trend may continue given the characteristics of the WLTP vehicles.

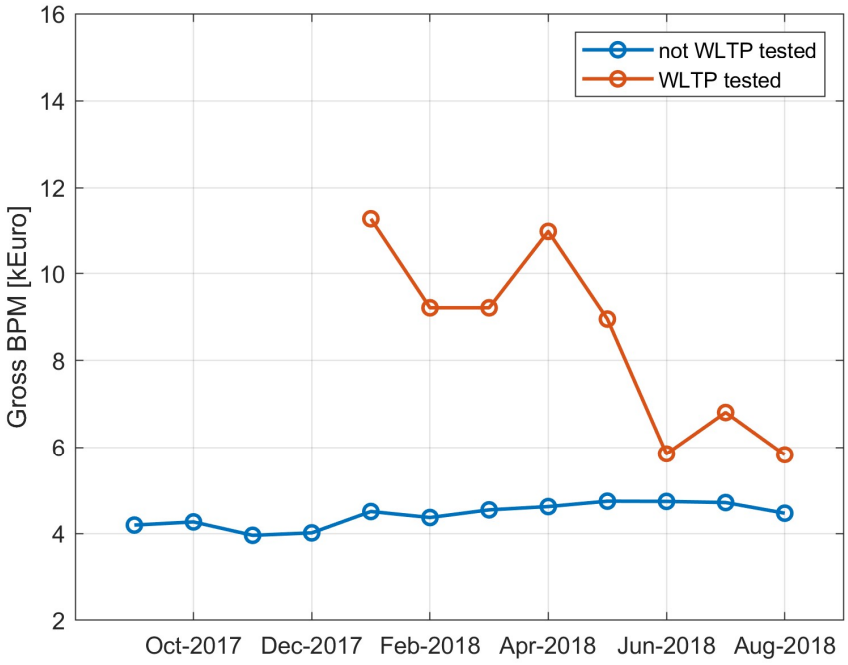


Figure 3-12 The BPM of WLTP vehicles is approaching that of NEDC vehicles, although NEDC vehicles seem to have a decreasing BPM in August, forcasting a trend with the end-of-series stock.

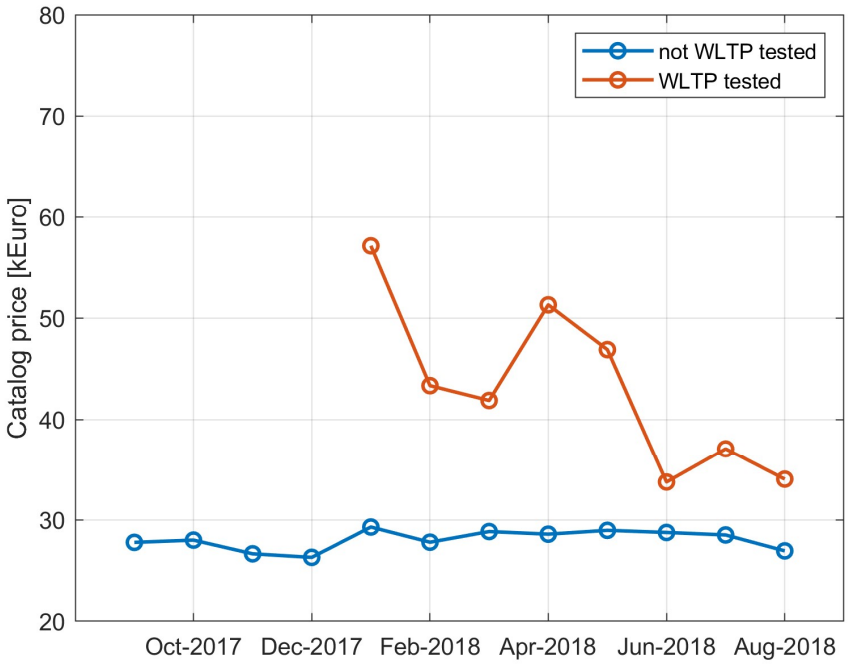


Figure 3-13 The catalogue price shows a similar trend as the BPM, although less pronounced.

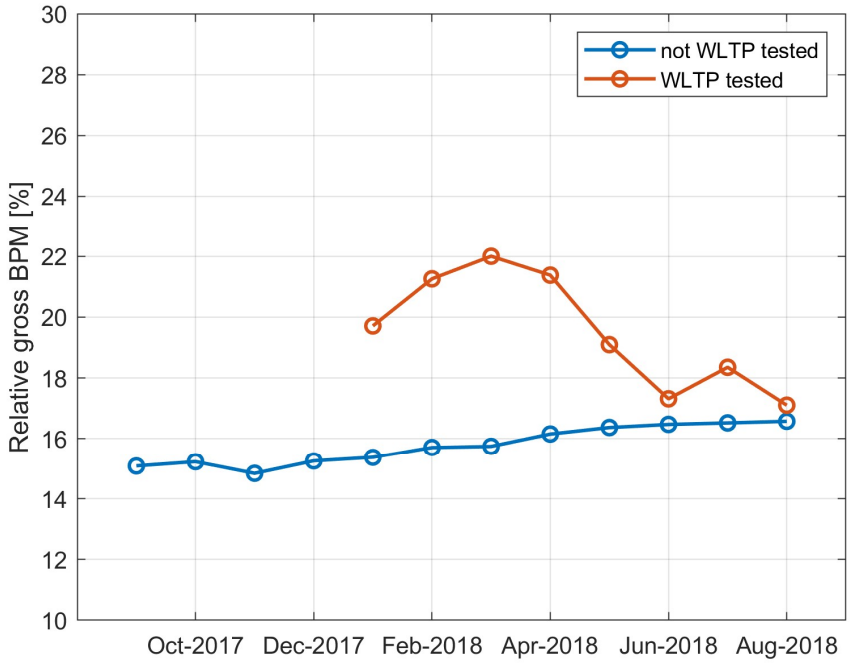


Figure 3-14 The BPM is almost the same fraction of the catalogue price in the third quarter, but initially the BPM was much higher, even relative to the catalogue price.

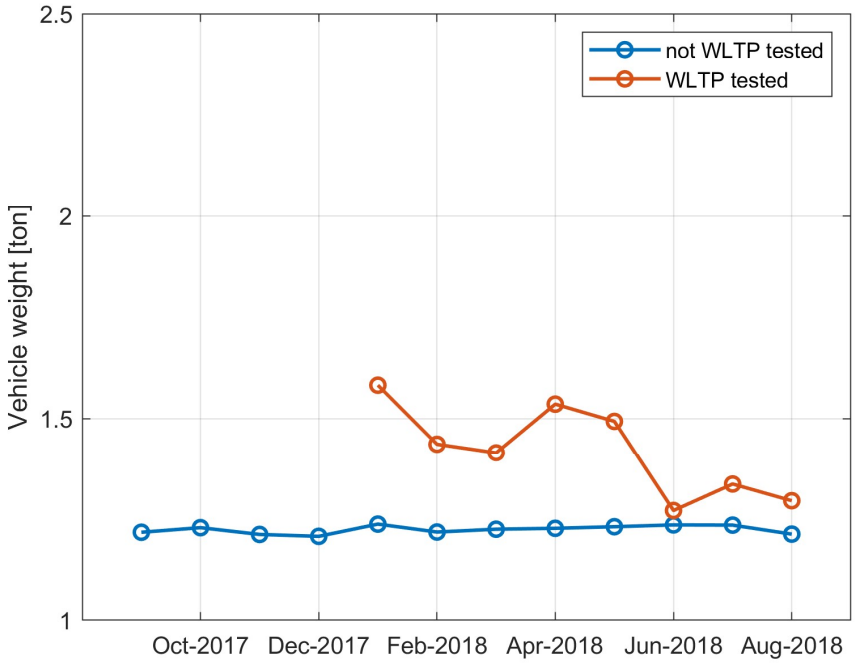


Figure 3-15 Vehicle weight of WLTP petrol cars follows the same downward trend as the CO_2 value.

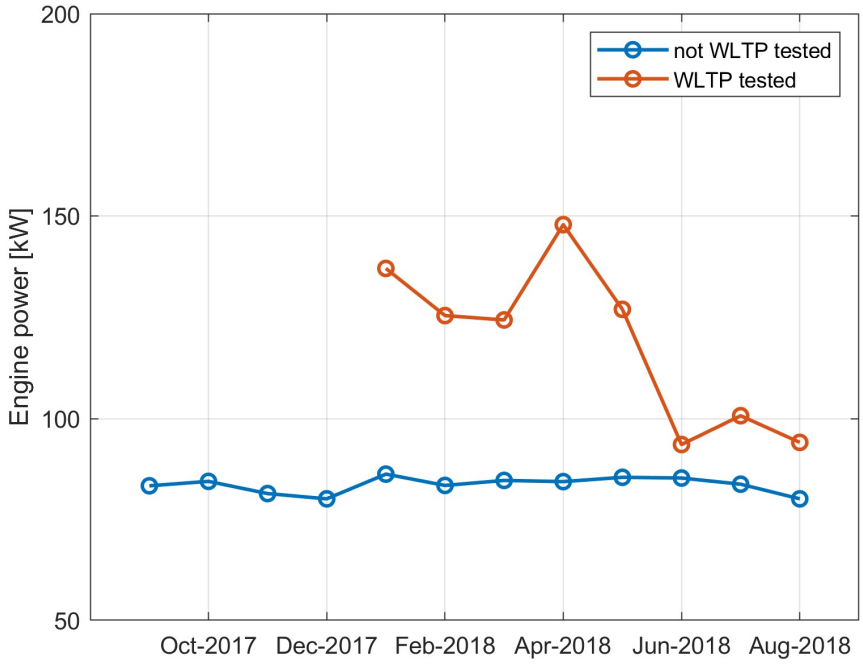


Figure 3-16 Although average engine power of WLTP cars is decreasing, a significant gap in engine power remains, as also the NEDC vehicles show a downward trend.

3.3 Diesel vehicles

The same analyses that have been presented in the sections 3.1 and 3.2 have also been performed for the subset of diesel vehicles registered in the same period. The results are presented in Figure 3-17 to Figure 3-24.

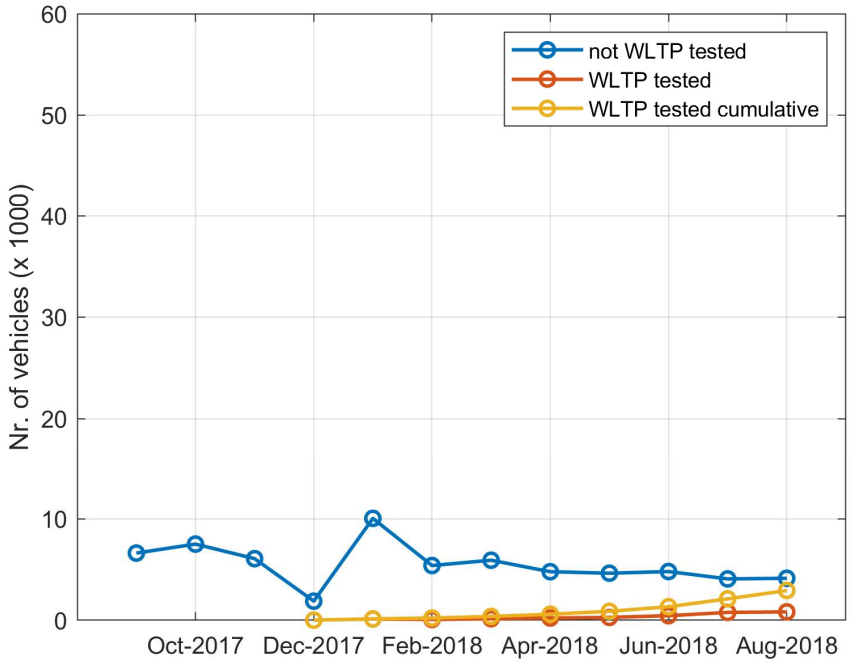


Figure 3-17 Diesel vehicles are a minor part of the total car registrations in The Netherlands.

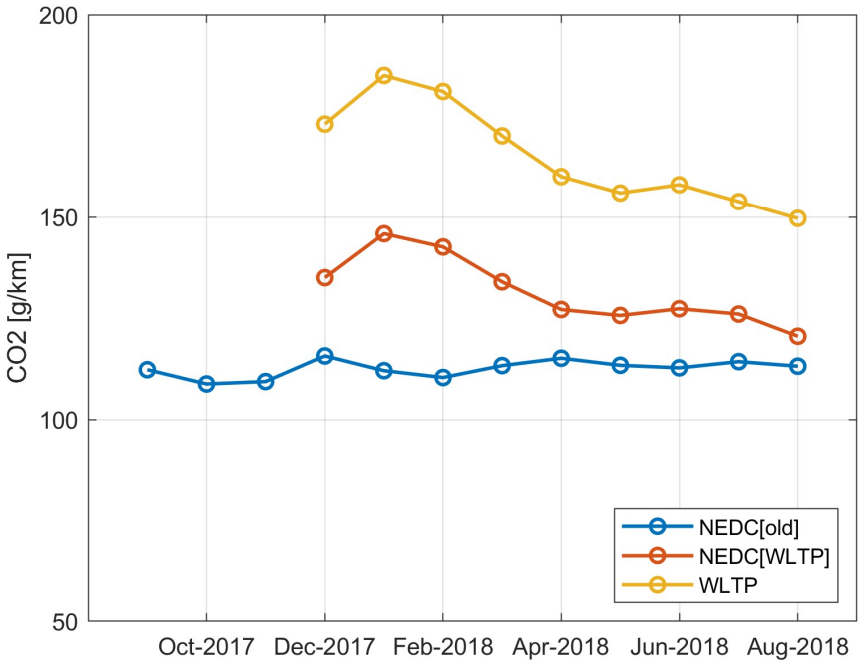


Figure 3-18 The monthly average NEDC[WLTP] CO_2 values show a monotonous downward trend, converging towards the NEDC value.

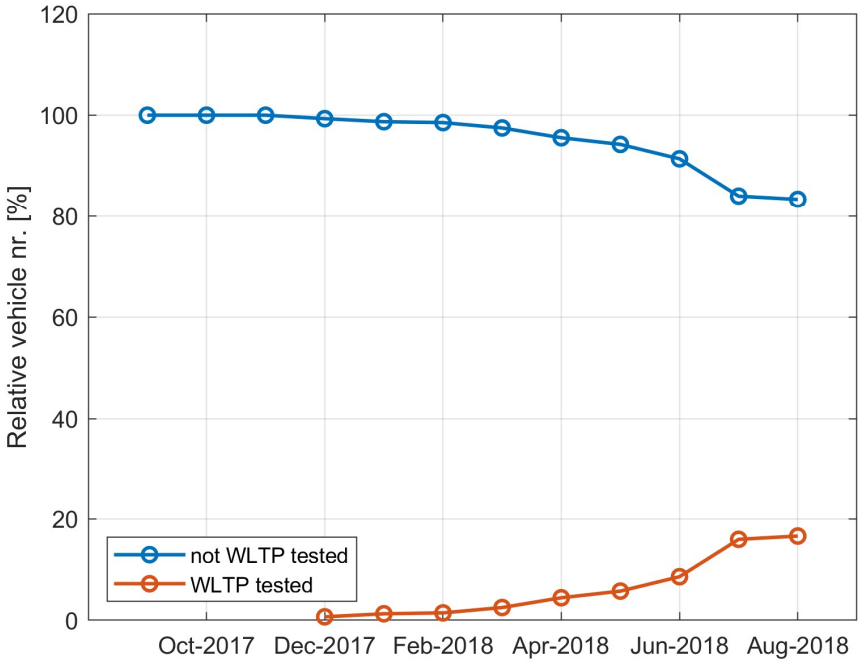


Figure 3-19 Fraction of WLTP diesel vehicles remains low although August 2018 is the last month new NEDC vehicles can be sold (apart from the end-of-series stock).

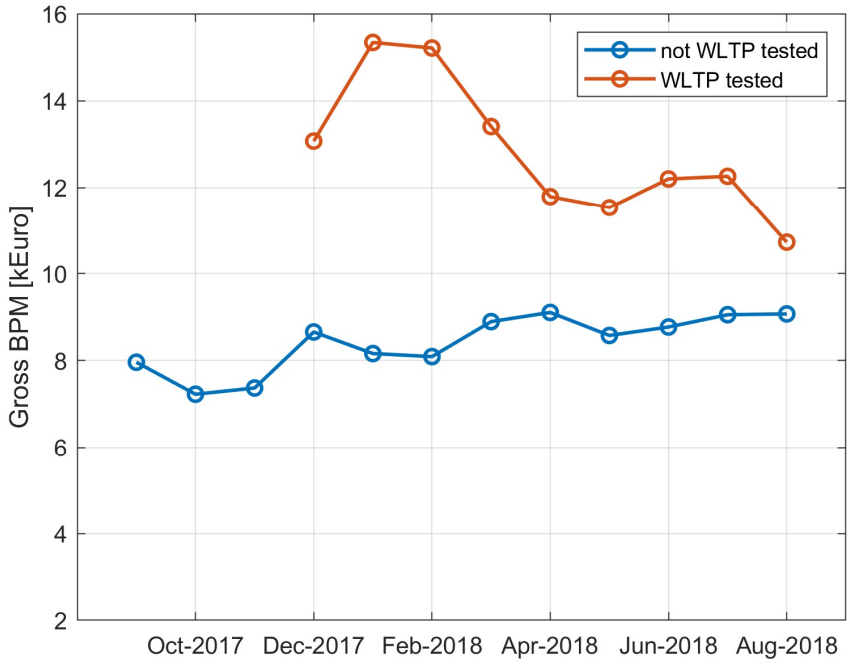


Figure 3-20 The monthly average BPM of diesel cars converges down toward the NEDC vehicles average BPM, although a gap remains.

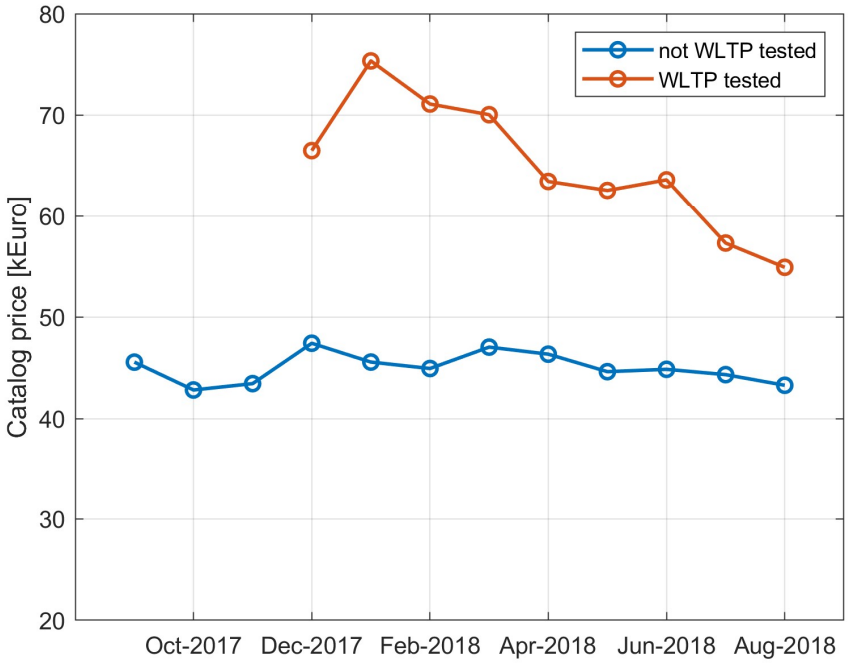


Figure 3-21 WLTP diesel cars have a significantly higher catalogue price than the NEDC vehicles. The gap is not expected to close.

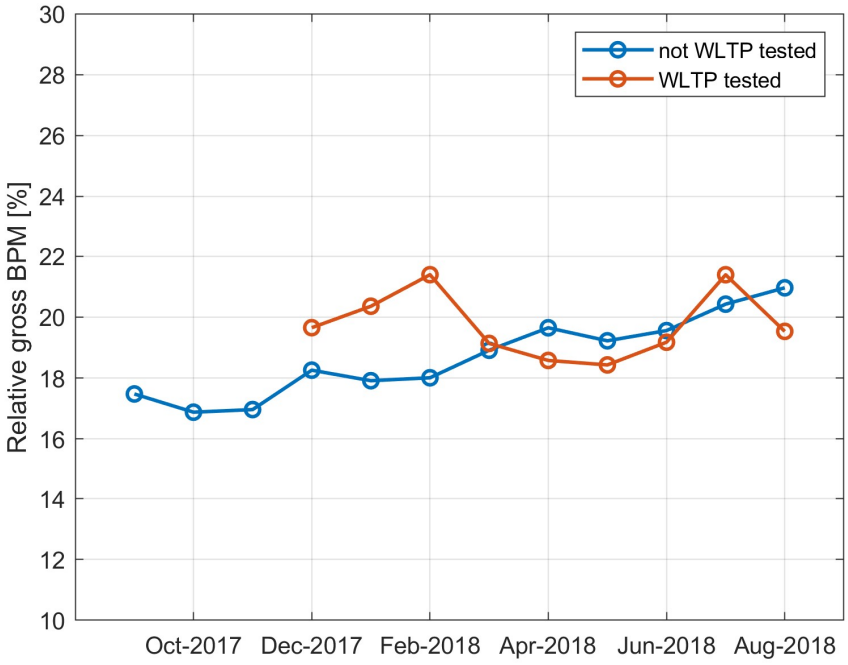


Figure 3-22 BPM of WLTP diesel cars remains more or less a constant fraction of the catalogue price. The differences in BPM and catalogue price between NEDC and WLTP is similar, but rising. Probably this is the effect of the economic growth.

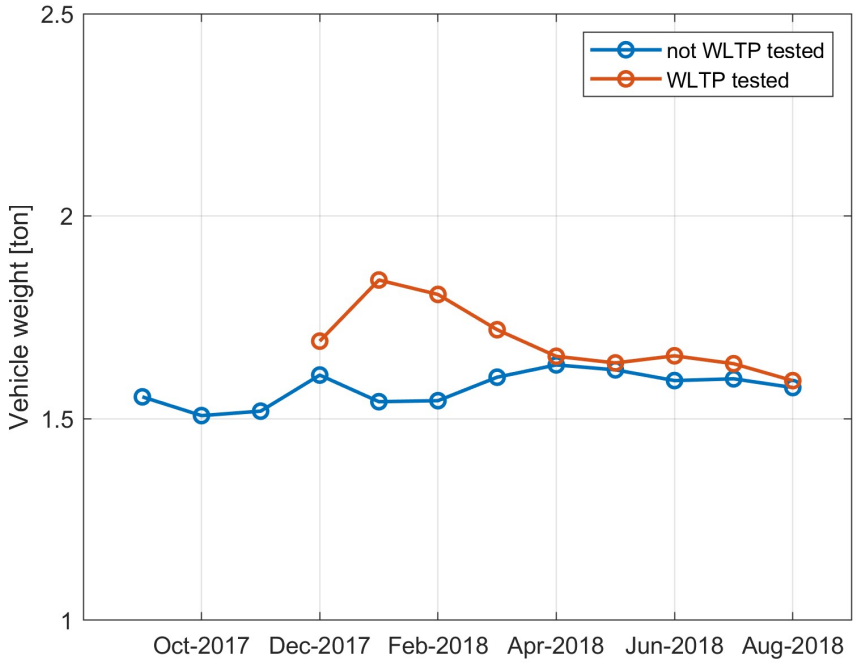


Figure 3-23 The mass of the two groups of diesel cars is very similar. Only in the initial months the WLTP vehicles had a higher mass.

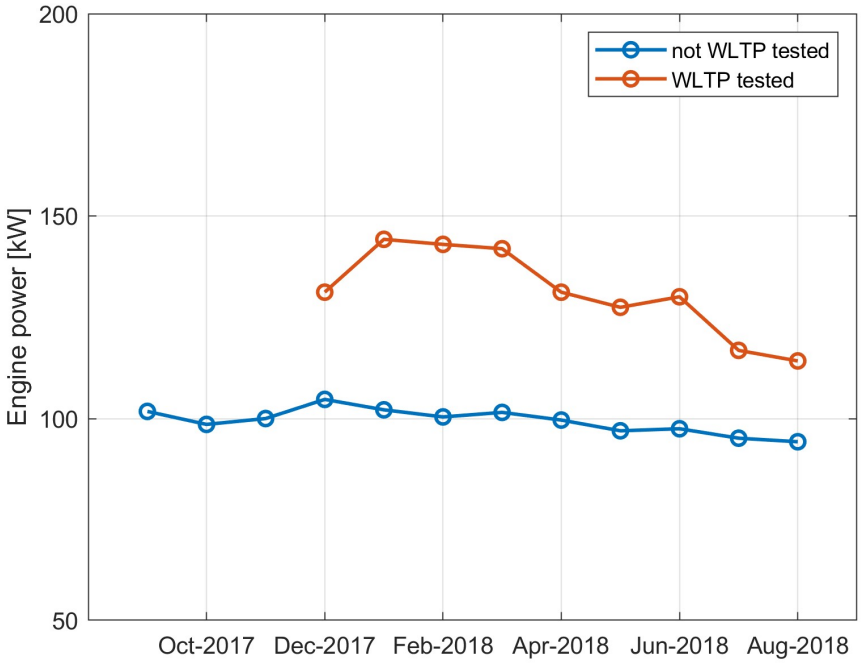


Figure 3-24 Although the average engine power of WLTP diesel cars is decreasing, a significant gap in engine power remains, as also the NEDC vehicles show a downward trend.

3.4 Comparable vehicles from regression analysis

Given the fact that all characteristics have a similar trend over time, the question remains if a gap between NEDC[WLTP] and NEDC[old] CO_2 values would exist, if the vehicle characteristics of the average WLTP and NEDC were the same. This can be analysed by extrapolating the trends, but also by fitting the CO_2 as function of vehicle mass and engine power for the four groups, of two fuels and two type-approvals. With the fit the same mass and engine power is inserted, to predict a CO_2 value based on the fit.

Table 3-1 CO_2 values in g/km of petrol and diesel cars for both NEDC and WLTP cars, if the vehicle characteristics mass and power were to be corrected to the same value for three typical vehicles. The correction factors used are derived from linear regression of weight and engine power dependency of cars in the RDW registrations.

Fit results	Compact petrol car	Midsize car	Large car
Characteristics	1000 kg, 50 kW	1300 kg, 80 kW	1700 kg, 130 kW
Petrol NEDC	94.3	124.9	167.3
Petrol WLTP	95.4	125.5	166.8
Diesel NEDC	-	98.3	132.3
Diesel WLTP	-	103.9	137.0

From the fit can be concluded that if the “same vehicle model” refers to the same weight and power, the petrol vehicles show a 1 g/km increase in CO_2 value from NEDC[old] to NEDC[WLTP]. For diesel vehicles the difference is 5 g/km. This is based on all new NEDC vehicles registered since 1-1-2017 and all WLTP vehicles registered. There is very little trend across vehicle sizes in this difference.

3.5 Trends in registrations

The NEDC[WLTP] CO_2 values of the first generation of WLTP cars was 25-30 g/km higher than the NEDC[old] CO_2 values of the NEDC cars sold in the same period. The average gap decreased to 9 g/km for the vehicles sold in August 2018 (see Figure 3-3). From all the vehicle characteristics presented in the previous sections, like mass, power, and price, it is clear that the average WLTP vehicle sold in the first three quarters of 2018 deviates significantly from the NEDC vehicles sold in the same period. In general changes to vehicle characteristics should not be considered to be a consequence of the NEDC - WLTP transition. A conservative estimate is that at least half of the gap observed in August 2018 - 9 g/km – can be attributed to different vehicle characteristics. If all the vehicle characteristics are converged to the NEDC values, there seems to be limited room left between the CO_2 value of the NEDC[WLTP] and the current NEDC.

4 Changes in vehicle model from NEDC to WLTP

In Chapter 3, differences in the average vehicle characteristics between NEDC and WLTP cars sold in the period up till 1st September 2018 have been analysed. In addition to this average comparison, a 1-on-1 comparison is made for individual models (NEDC vehicle to WLTP vehicle comparison).
For common WLTP vehicle models with substantial sales, i.e. at least 100 vehicles for one WLTP vehicle model registered, the average of the make and model under NEDC has been compared to the same make, model, and fuel type, under WLTP. A large variety of vehicle models are available in the CoC, but the actual registrations are a good indication of the change in vehicle characteristics from NEDC to WLTP transition. For petrol vehicles there are more WLTP models with sufficient statistics (26 petrol models in total) than for diesel vehicles (only 7 models).

Only a few models show a substantial change in characteristics, such as weight, engine power, and catalogue price between the NEDC model and WLTP model. Most vehicle models available as WLTP vehicle made a smooth transition from the NEDC model. The NEDC[WLTP] CO_2 value is higher than the NEDC[old] value. Typically, the increase is around 10 g/km. However, given the fact that the total number of WLTP registrations is small, it may be a preliminary batch and a specific (biased) part of total future WLTP registration. Therefore, the difference in CO_2 value must be taken only as indicative.

The real question in this chapter is, if despite the same vehicle model name, the WLTP vehicle is distinctly different from the predecessor NEDC model. Generally, this change is limited. However, some vehicles have substantial higher engine power. Also, the vehicle mass of the new model is higher than of the old model. However, the change in CO_2 value due to a mass increase is limited. The changes for a given model, in the transition from NEDC to WLTP, are mainly an indication that the vehicle is different, even though the name is still the same. But if the WLTP vehicle is significantly different from the NEDC vehicle, the new model might be sold for a longer period, most likely also in the year 2021. 2021 is the target year of the European CO_2 standards for passenger cars. Taking into consideration that car manufacturers on average have to achieve – roughly – another 25% reduction in NEDC CO_2 values between 2018 and 2021, one might expect new vehicles to have significantly lower CO_2 values. This has not been observed in the data available and suggests the car manufacturers will come up with a second step in NEDC – WLTP transition in the coming years.

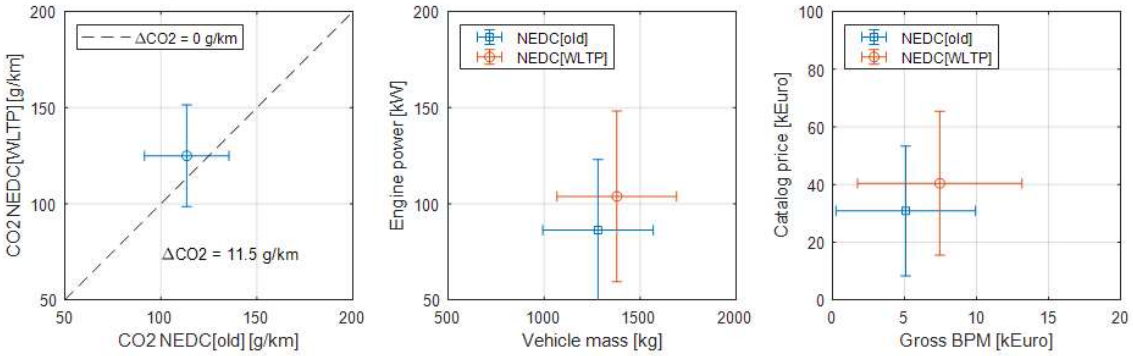


Figure 4-1 The average difference between WLTP and NEDC cars from the small 1-on-1 comparison of RDW registrations. NEDC CO_2 value (+11.5 g/km), vehicle mass, engine power, BPM and catalogue price all have gone up by a significant amount in the transition from NEDC to WLTP. The bars indicate the spread in the values for the individual registrations; the spread is larger than the differences in averages observed.

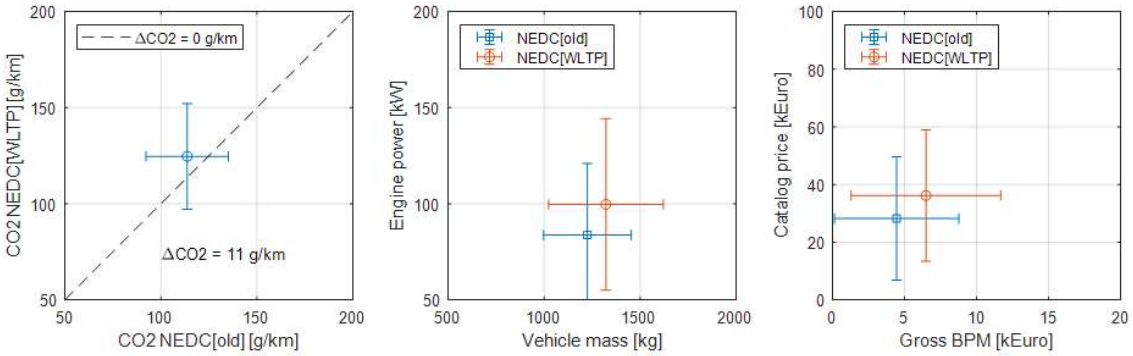


Figure 4-2 For **petrol** vehicles the differences in CO_2 values and vehicle characteristics linked to the NEDC – WLTP transition are slightly smaller than for diesel vehicles (figure 4-3)

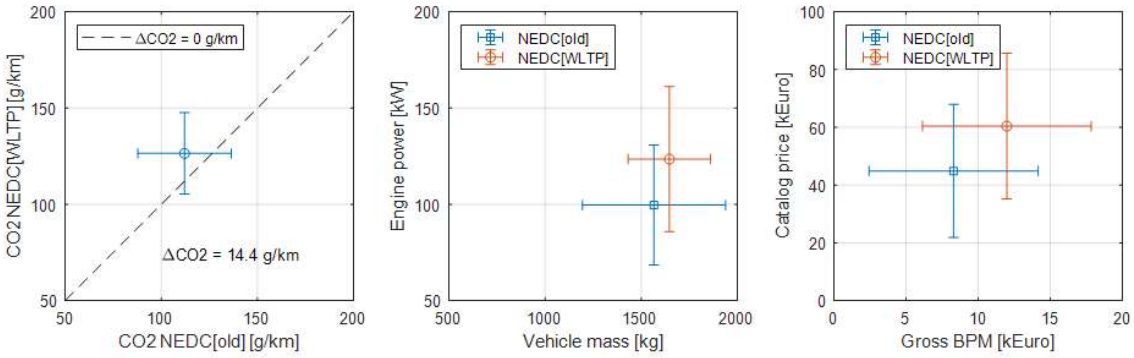


Figure 4-3 For **diesel** vehicles especially the power increase in the NEDC – WLTP transition is significant. Catalogue price and BPM have the same relative difference.

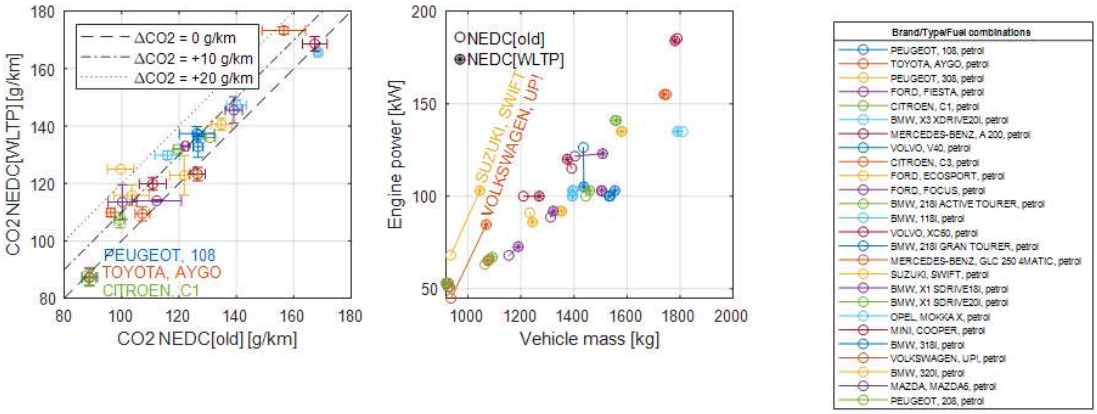


Figure 4-4 For individual petrol vehicle models the NEDC[WLTP] and NEDC[old] CO_2 values, as well as the change in vehicle characteristics mass and engine power. Open circle indicate the NEDC characteristics, the solid circle the WLTP characteristics of the same model. A line shows the direction of the change. Only a few models have a large average change in the transition from the NEDC model to the WLTP model.

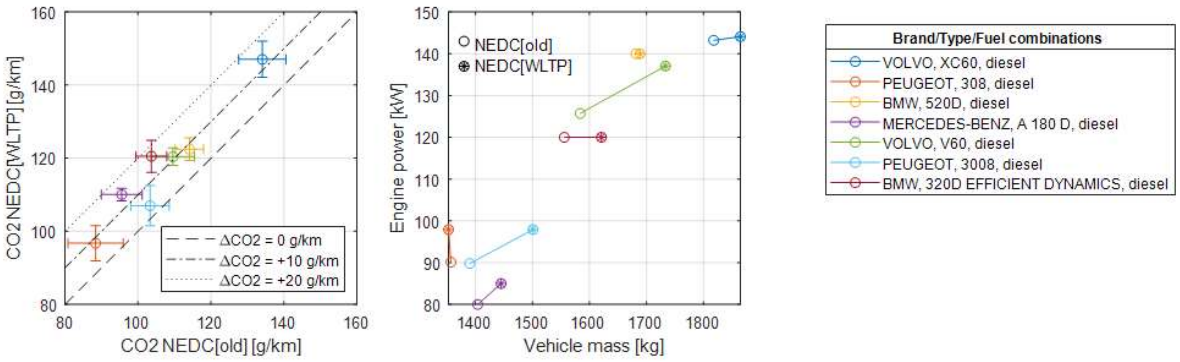


Figure 4-5 For individual diesel vehicle models the NEDC[WLTP] and NEDC[old] CO_2 values, as well as the change in vehicle characteristics mass and engine power. For diesel vehicles fewer models have enough registrations to compare the average. The changes are, however, larger than of petrol cars.

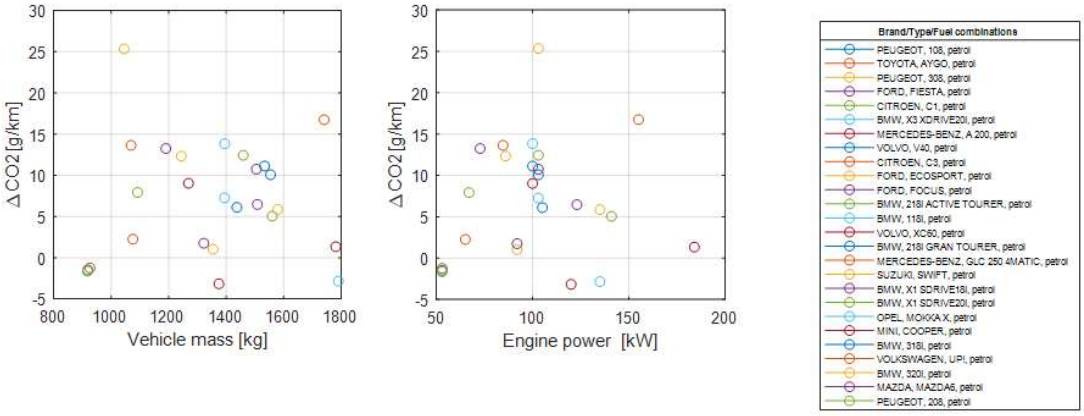


Figure 4-6 For petrol vehicles the delta between NEDC[WLTP] and NEDC[old] CO_2 values plotted against vehicle mass and engine power. Although the NEDC CO_2 value increases from NEDC vehicle to WLTP vehicles there is no clear relation with engine power or mass of the models.

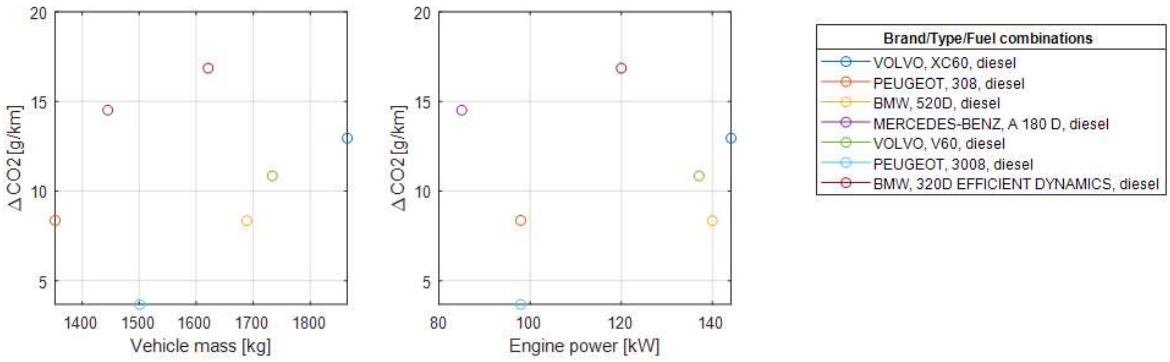


Figure 4-7 The delta in CO_2 for diesel cars has no discernible relation with vehicle characteristics. The variation is larger than the average gap.

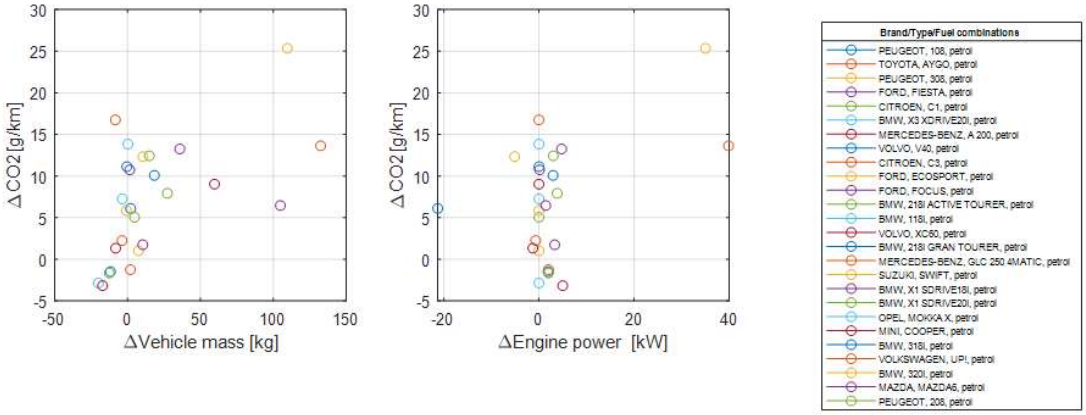


Figure 4-8 For petrol cars there seems to be a limited correlation between change in mass and power and delta in CO_2.

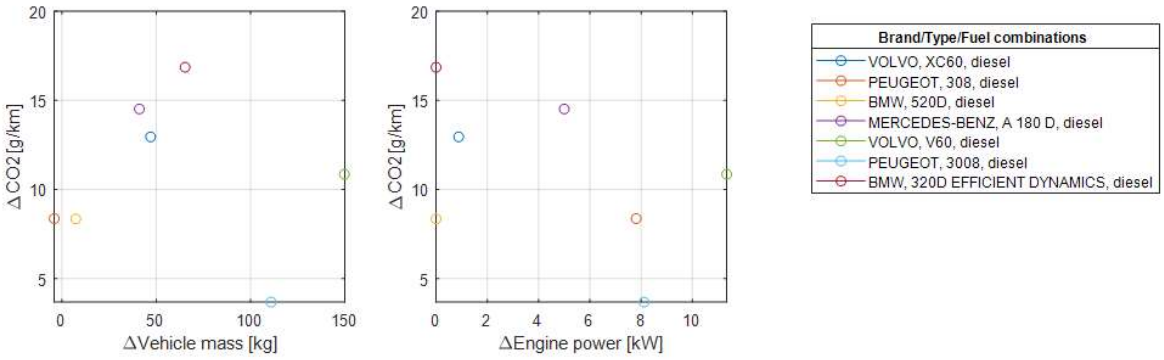


Figure 4-9 For diesel cars there seems to be no correlation between the physical parameters; mass and power, and the delta in CO_2 value.

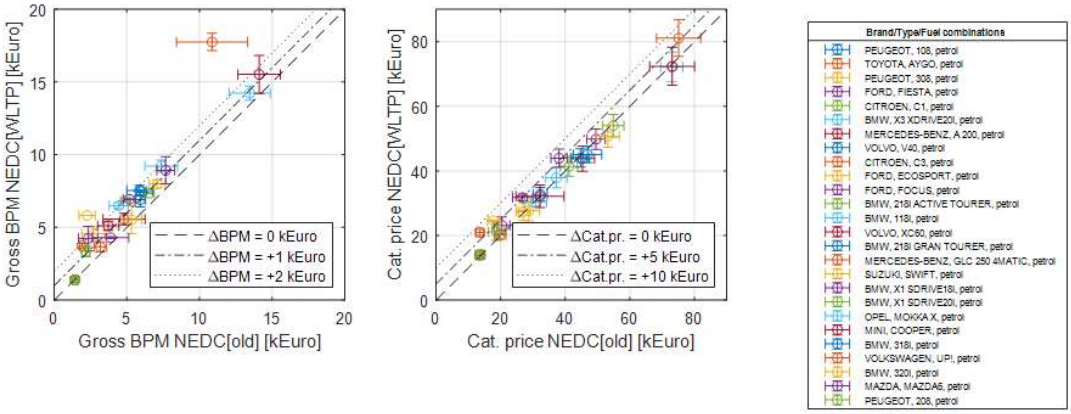


Figure 4-10 For petrol cars the typical increase in BPM is associated with an increase in CO_2 values of the WLTP vehicles. The catalogue price of the same model increases little.

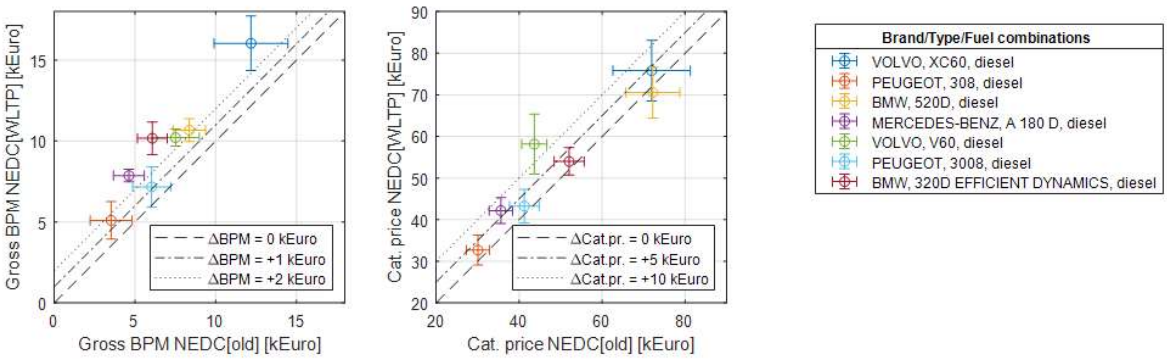


Figure 4-11 For diesel cars however both the catalogue price and the BPM show similar increases across the transition, however, both are only weakly correlated.

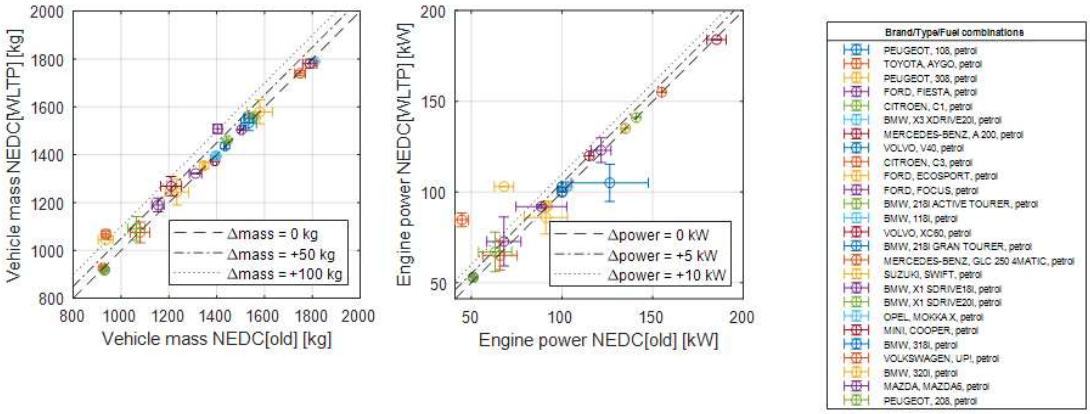


Figure 4-12 For petrol cars vehicle mass shows limited increase with the transition to WLTP, except for a few models. And no significant increase in engine power, except for a few models.

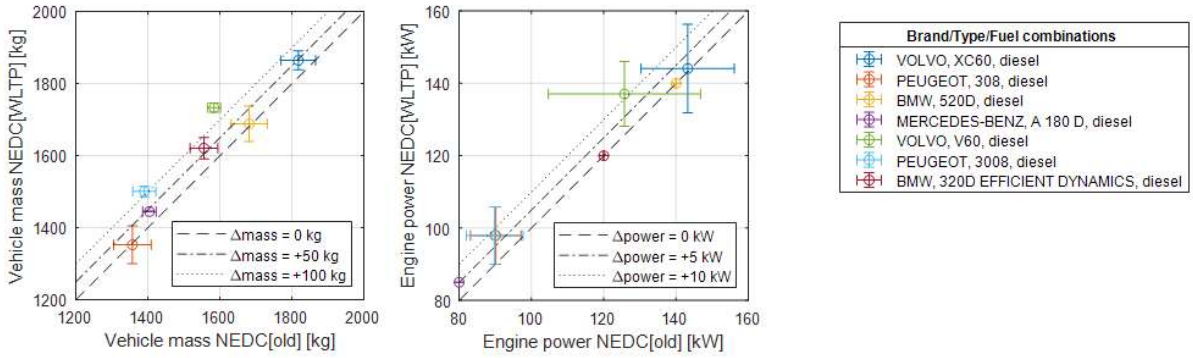


Figure 4-13 For diesel vehicles the physical characteristics show a trend to heavier and more powerful vehicles. For diesel vehicles there is larger spread, i.e., more variation, within one vehicle model.

4.1 NEDC[WLTP] and WLTP CO_2 values of WLTP vehicle models

The vehicle models with sufficient number of registrations can also serve as a first indication of the delta between NEDC[WLTP] and WLTP CO_2 values. A large spread in delta's can be observed, but the delta is commonly more than 20 g/km, with an average of around 30 g/km. For petrol vehicles some dependency of vehicle size is observed. For smaller vehicles, with lower CO_2 values of 80 g/km to 140 g/km, the gap seems in the order of 20 g/km, while for higher CO_2 values the gap is large, but with a larger spread. See Figure 4-14 and Figure 4-15.

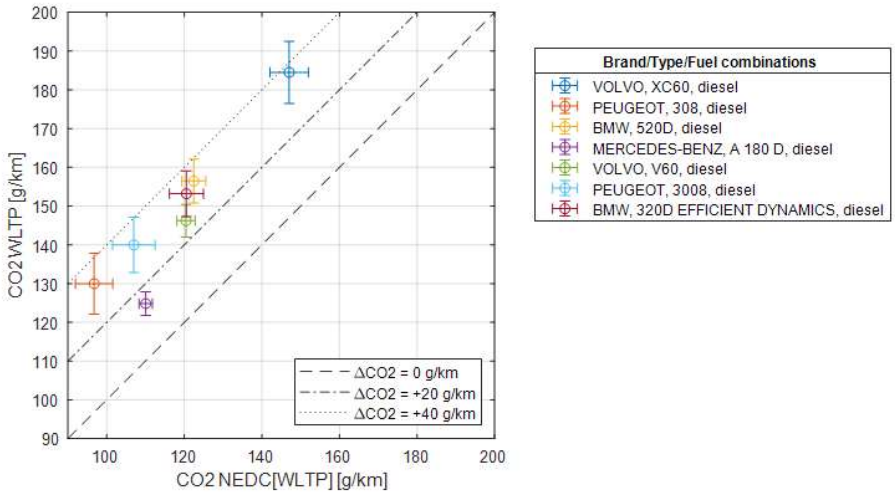


Figure 4-14 The NEDC[WLTP] and the WLTP CO_2 values of the diesel vehicle models with sufficient registrations.

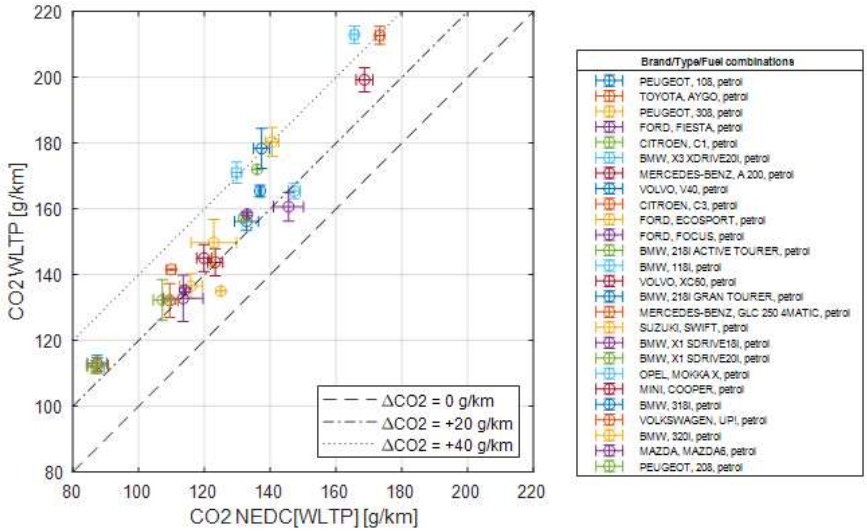


Figure 4-15 The NEDC[WLTP] and the WLTP CO_2 values of the petrol vehicle models with sufficient registrations.

5 End-of-series vehicle stock

As of 1st September 2018 NEDC cars can be registered in The Netherlands if the cars have been produced , are present in the EU and have been registered as end-of-series stock at the RDW. Car dealers and importers had until the 14th of September 2018 to register the vehicle stock of NEDC vehicles at the RDW. About 90,000 NEDC vehicle have been signed up, which would cover approximately a quarterly sales. RDW supplied the lists of vehicles, with limited details. In this study about 68% of the stock registrations could be matched with a CO_2 value. These vehicles exhibit on average a 3.5 g/km lower CO_2 value compared to the NEDC vehicles which have been sold over the last year. This is mainly due to the lower CO_2 values of the petrol cars in stock. Diesel vehicles in stock have on average a higher CO_2 value. See Table 5-1.

Table 5-1 Average NEDC[old] CO_2 value of the cars registered as end-of-series stock in The Netherlands compared to the CO_2 value of all cars sold in The Netherlands in the period September 2017 – August 2018. Source: RDW, specific one-off data delivery to this project.

NEDC[old] (g/km)	NEDC cars registered Sept.'17 – Aug.'18	NEDC cars signed up for end-of-series stock
Petrol	113,7	108,1
Diesel	112,1	130,8
Total	113,5	110,0

Given the current gap between NEDC[old] and NEDC[WLTP], the end of stock series, which are likely to dominate the sales until early 2019, will add substantially to this gap between the NEDC[WLTP] and the NEDC[old] in the last quarter of 2018. The NEDC petrol vehicles in stock have on average 5.6 g/km lower CO_2 values than the NEDC vehicles sold. The fact that current NEDC stock has lower CO_2 values than the NEDC vehicles sold in the last year may indicate vehicles were also selected on this criteria. According to the RAI-Vereniging this has to do with the high percentage of smaller petrol cars in the stock; sales of smaller and thus less expensive cars are considered to be more sensitive for possible increases in BPM purchase tax. If there remains a gap between the NEDC[WLTP] and the NEDC[old] vehicles sold in the last quarter, in part it might be due to the selection of stock for the end-of-series.

Cars in the end-of-series stock don't necessarily have to be sold in The Netherlands, they can also be sold in other countries. In addition to the end-of-series stock new NEDC cars registered in other countries can be imported as well.

6 Variations in CO_2 for WLTP vehicle models

With the introduction of WLTP, each individual vehicle sold will have its individual WLTP CO_2 value. In theory for the same type-approval, variant, and version there can be a difference in CO_2 values of up to 30 g/km. This is the whole range of the available options on a specific vehicle model. In the database of RDW CoC's, differences of up to 15 g/km have been observed. The differences are mainly related to the wheels and tyres mounted on the vehicle.

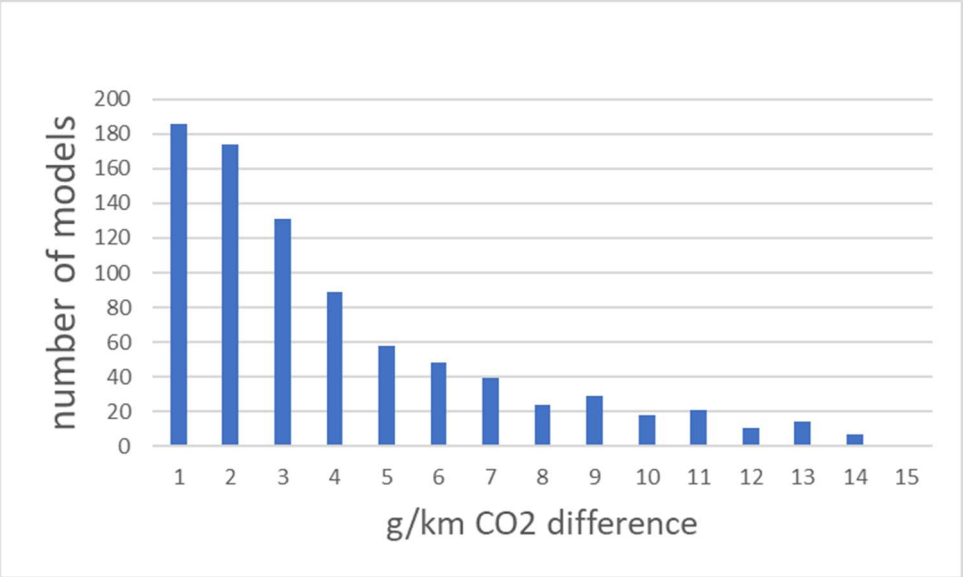


Figure 6-1 The variation in WLTP CO_2 for the same vehicle model. Source: RDW CoC's of WLTP cars.

For NEDC[old], this kind of differences in CO_2 were not included: vehicles of the same model with different options all had the same CO_2 value, typically at the low end of the full range. The possibility to have a lower CO_2 value, based on a trimmed down version of the vehicle model seems to be limited by the introduction of the WLTP. The NEDC[WLTP] CO_2 values may vary for the same type-approval, variant, and version. This data is not always properly available, but a 3 g/km average difference seems typical, based on the largest gap in WLTP values for the same type-approval, variant, and version. Hence, not all of the variations of CO_2 with different options for the same type-approval, variant, and version, are covered in the NEDC[WLTP] CO_2 value. More than half of the variation finds its way to this CO_2 value.

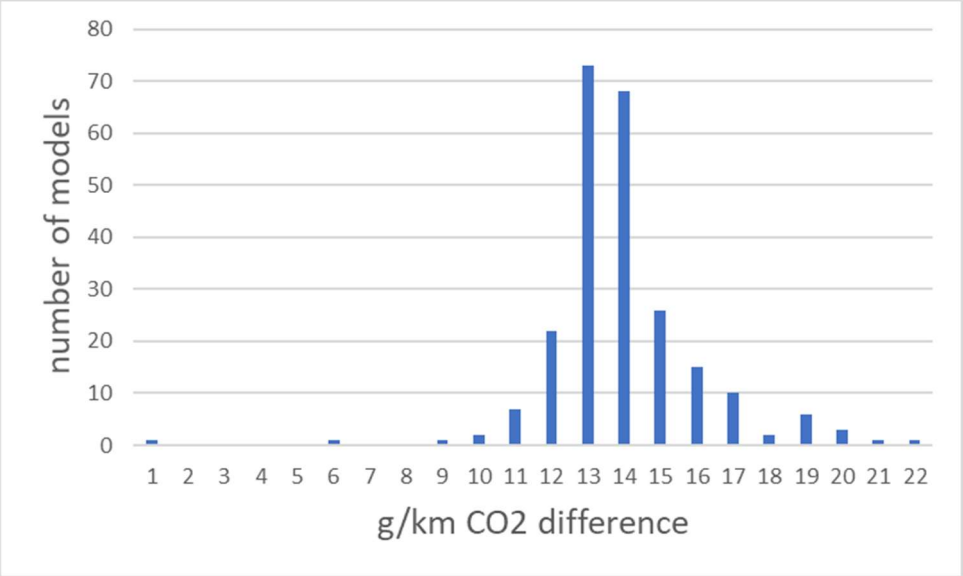


Figure 6-2 The variation in NEDC[WLTP] CO_2 for the same model, based on the largest WLTP variation.

The wheels and tyres seem the main cause of variation in WLTP CO_2 declaration on the same vehicle model. For the group of vehicle models that have a range of over 10 g/km difference between different CoC's, the difference in maximum and minimum rolling resistance is on average 77 Newton, translating into 11 g/km. This is based on multi-regression analysis on this dataset. The weight differs on average only 39 kg, which accounts for 2 g/km CO_2 difference on the WLTP. Most models are available with tyre label B, with A and C as alternatives. In many cases they seem related to the wheel size, e.g. wider rims, and sport wheels. This may also explain in part the higher weights, since larger and wider sport wheels are generally heavier than the standard steel rims.

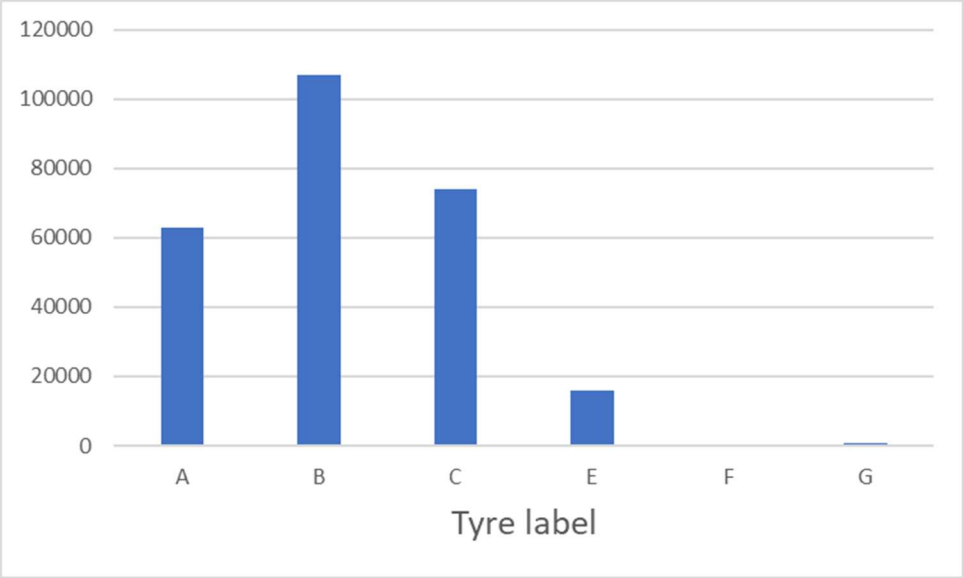


Figure 6-3 Distribution of tyre labels on individual CoCs. Label B seems to be the common tyre label fitted to a WLTP car.

Under NEDC[old] the same CO_2 value, typically at the low end, could be used for the whole range of vehicles. Under NEDC[WLTP] CO_2 values do vary for the same type-approval, variant, and version. This explains in part the higher NEDC[WLTP] CO_2 value compared with NEDC[old].

7 Conclusions

From the 1st of September 2018, no new NEDC passenger cars and small vans can enter the European market. Hence the 1st of September is an appropriate date to determine the midterm situation of the transition from NEDC to WLTP. Given the fact that car dealers and importers had until the 14th of September to register the end-of-series stock, the current study is based on the vehicle registrations and model availability on the 1st of September, combined with the stock on the 14th of September. On the reference date however, insufficient information was available to perform the evaluation to its full extend and to establish results representative for the development of CO_2 values related to WLTP introduction. The data availability is expected to increase significantly over the next few months. It is expected that the true picture on the transition from NEDC to WLTP vehicles will only be clear early 2019, when the NEDC stock is to be almost depleted, given the 90.000 NEDC vehicles still in stock. In phase 3 (due in May 2019) a more comprehensive analyses will be presented.

The 1-on-1 comparisons on both the RDW and RAI datasets indicate a 11-12 g/km difference between the NEDC[WLTP] CO_2 value of a WLTP car and its equivalent former NEDC car (see paragraph 2.2 and Chapter 4). On the macro level, the analyses of the RDW dataset show a strong decrease in the course of 2018 of the difference between the average NEDC[WLTP] and average NEDC[old] CO_2 values. Simultaneously the number of registration increased. In August 2018, the difference was 9 g/km (see paragraph 3.1).

For the last quarter of 2018 the end-of-series stock of NEDC vehicles will play a significant role in the total sales. The true transition to WLTP is expected to be effective only as of early 2019. The NEDC stock has 3.5 g/km lower CO_2 values than the NEDC vehicles sold in the last year (see Chapter 5). The end-of-series NEDC vehicles will have a lower CO_2 value than the vehicles sold up to September, retaining a larger gap between NEDC[WLTP] and NEDC[old] vehicles in the autumn, than based on the trends of the first three quarters of 2018. Since the number of registrations of NEDC vehicles is expected to drop significantly, a better comparison from now on, would be the total sales of 2018, instead of the month-by-month comparison between NEDC[WLTP] and NEDC[old] values of the last month of 2018.

The developments on the macro level indicate that the first batch of WLTP registrations mainly consisted of larger and more expensive cars. Since May 2018 the main characteristics of WLTP cars converge towards the average NEDC car, but a difference still remains. If the remaining differences in the vehicle characteristics mass and power are corrected for, only a 1 g/km difference for petrol cars and a 5 g/km difference for diesel cars would remain on the macro level in August 2018 (see paragraphs 3.4 and 3.5). No indications have been found, that the delta in CO_2 values between NEDC[WLTP] and NEDC[old] is somehow related to the CO_2 value of the car or its vehicle segment (see paragraph 2.2.1.2).

So far, there is a limited number of vehicle models for which the transition from NEDC to WLTP can be examined on individual model level (see chapter 4). This includes 26 petrol models and 7 diesel vehicle models. Five of the 26 petrol models

show a significant change in characteristics, like mass and power, while 6 of the 7 diesel models have clearly visible different characteristics. Very likely, diesel vehicles had to be redesigned to satisfy the new vehicle emission legislation, WLTP and RDE, while most petrol vehicles can fulfil the new requirements with limited adaptations. The delta in CO_2 values between NEDC[WLTP] and NEDC[old] is 4 g/km higher for diesel than for petrol cars (see paragraphs 2.2.1.1 and 3.4).

Very likely over the whole of 2018, a gap of 5-9 g/km between NEDC[WLTP] and NEDC[old] is to be expected, as the majority of the NEDC vehicles are already sold, while half of the WLTP vehicles for 2018 are expected to be sold from 1st September 2018. The bandwidth is determined mainly by the extent in which the end-of-series stock dominates the sales in the last quarter. If from September WLTP vehicle registrations are 50% or more, the last quarter will be determining the WLTP average, given the low fraction, below 20%, in the months before. With the convergence of NEDC[WLTP] towards NEDC[old] the current distance of 9 g/km is the upper limit, even with the low CO_2 NEDC vehicles in stock.

It's hard to predict the development of the average NEDC[WLTP] CO_2 values for the near future on the basis of the analysis of the datasets available in phase 2 of this project. The development on the macro level in the last three months deviates from the trend in the first months of 2018 (see the trendlines in figure 3-3). The developments observed on the macro level deviate from the 1-on-1 comparisons. None of the approaches is considered to be fully representative.

- The macro level on the one hand is hampered by the limited number of WLTP car registrations. It's likely WLTP cars have been brought to the market in particular if the former NEDC car was close to WLTP compliance. And also the smaller and lighter cars seem to be under-represented in the WLTP registrations. See figures 3.2, 3.5, 3.7 and 3.8).
- On the other hand in the 1-on-1 comparisons important brands and models are missing. The RAI dataset is comprehensive but not covering the full car market. The 1-on-1 comparison of the RDW dataset could only be performed on a limited number of car models.

Several elements considerably add to the uncertainty in the future development of the average NEDC[WLTP] CO_2 values on the macro level:

- The standard deviations of almost all results are comparable to or larger than the observed effect (see for instance Figure 4.1).
- The large spread among car brands, indicating that manufacturers all have their own interpretation and strategy in the NEDC – WLTP transition (see paragraph 2.2.1.3).
- The elements determining the differences between WLTP and the former NEDC method can only be quantified, and thus explained, to a limited extend (see Figure 7-1).

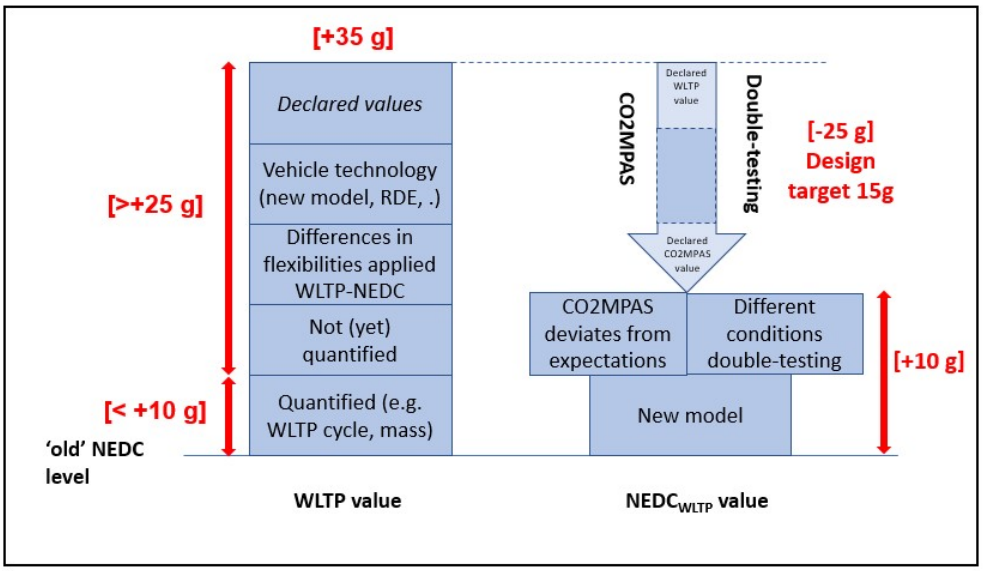


Figure 7-1 Schematic overview of elements determining the difference between WLTP and the former NEDC method. The sizes of the blocks are no indication of the effects. The elements can only be quantified to a limited extend. The figure is an update of the figure presented in the phase 1 report: also in the conversion of WLTP CO_2 values to NEDC[WLTP] CO_2 values declared values can be used.

It may be that WLTP vehicles sold will remain to have on average different characteristics as the NEDC vehicles sold over the last year, as has been the case in the first three quarters of 2018. The comparison between the NEDC CO_2 values is then biased by the changing market. Any difference is probably related to the economic growth. The different characteristics seem to be the dominant effect in the gap in CO_2 values, of NEDC and WLTP vehicles.

The meaning of the NEDC value has changed with the transition to WLTP. Therefore, throughout the report it is referred to as NEDC[WLTP] and NEDC or NEDC[old]. From the CoC's it is clear that the new NEDC[WLTP] value is based on the WLTP testing and procedures. Each individual WLTP CO_2 value is linked to a NEDC[WLTP] value. In the past the NEDC CO_2 value of different versions had the same CO_2 value based on one model. This loophole to lower the CO_2 value for vehicles with more options, different tyres, and a larger body is clearly closed off (see chapter 6).

The WLTP value remains consistently higher than the NEDC[WLTP] value, for all fuels and brands. Since there are no consequences to the declared WLTP value until 2021, this difference is likely to persist.

In order to comply with the European CO_2 standards of 95 g/km the average CO_2 value of new cars to be sold in Europe will have to decrease by 20-25% between 2018 and 2021. At a national level in The Netherlands the decrease has to be approximately 15%. To close the gap the improvement will have to come from WLTP cars, as no new NEDC cars can be registered, apart from the limited number in the end-of-series stock. In this respect it's remarkable that no fuel efficiency improvements have been observed between the newly introduced WLTP cars and their predecessors, while in general (re)new(ed) models used to be more fuel efficient than their predecessor and used to be on the market for at least a couple of

years. It has been widely reported that car manufacturers are currently still performing numerous tests to apply for new WLTP and RDE type-approvals. Before long a large amount of new type-approvals will be issued with lower NEDC[WLTP] CO_2 values (2019-2020) and much lower WLTP CO_2 values. This means the type-approvals that have been issued so far are part of an intermediate round: a first batch of WLTP type-approvals that will be on the market for only a limited period of time. Every car manufacturer seems to have its own approach and strategy to cope with the introduction of the WLTP. It is expected that the stability in CO_2 values will return no earlier than 2021.

8 Signature

The Hague, 11 October 2018 TNO

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