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Passenger Car Emissions: Standard and Real-World Fuel Consumption

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AK WIEN

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Study on behalf of the Vienna Chamber of Labour (*AK Wien*)

Holger Heinfellner, Nikolaus Ibesich, Günther Lichtblau, Christian Nagl, Barbara Schodl, Gudrun Stranner

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PREFACE

The discussion about the growing gap between manufacturer specifications in their sales brochures and real-world fuel consumption and emissions of new cars has started again. In addition to the fixing of tests by a big manufacturer of passenger cars, an approval procedure for tests is under suspicion which calculates – with a lot of “flexibility” – standard consumption levels significantly below real-world consumption levels, which allows car manufacturers to easily stay below the CO_2 requirements of the European Union. This standard consumption level of new cars is, however, the starting point for environmental policies, taxation and also for consumers when deciding which car to purchase.

This issue is the subject of this study, which the Vienna Chamber of Labour (*AK Wien*) commissioned the Environment Agency Austria with in June 2015. For the first time in Austria and based on registration statistics and representative European consumption databases, this study should provide an objective survey on the extent of divergences between manufacturers‘ specifications and real-world consumption. The basis for this survey was car registration data including motorisation (Statistics Austria) of the 30 models with the most new registrations in Austria between 2000 and 2013.

The calculation of real-world fuel consumption levels has been expanded to include real-world emissions of nitrogen oxide (NO_x), since modern diesel cars, in particular, are under suspicion of emitting more NO_x than would be expected based on their type approval.

The Vienna Chamber of Labour (*AK Wien*) sees the present study as a first impetus to change the existing system of approval procedures for tests within the EU. In particular, new testing schemes, which calculate real-world fuel consumption, are necessary, as well as a control system for new cars already used in traffic regarding their conformity of manufacturers’ specifications and real-world emissions. It is very important for the Chamber of Labour that consumers can rely on fuel consumption data and are not confronted with unexpected additional costs. Furthermore, traffic as the main source of CO_2 emissions, needs to contribute to climate protection not only in theory, but also by way of reduced real-world fuel and emission figures. The deficits proven in this study, as well as the incidents in the US regarding real-world emissions of a German manufacturer strongly support our calls for action.

Rudi Kaske

President, Vienna Chamber of Labour

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1 SUMMARY

Since passenger cars are a significant source of CO_2 emissions (approx. 17% of national CO_2 emissions in 2013), the European Commission designed strategies to reduce CO_2 emissions from passenger cars in 1995. In December 2009 Regulation (EC) No 443/2009 was adopted, according to which manufacturers had to mandatorily reduce CO_2 emissions from new passenger cars to 120 g CO_2/km by 2015. The target of 95 g/km is set for 2021. According to the analysis of CO_2 monitoring data, the manufacturers will reach the target for 2015.

The data for CO_2 monitoring is, however, based on test results which are calculated in a laboratory using a set driving profile, a test cycle called “New European Driving Cycle – NEDC”. Europe-wide measurements show that there is an ever increasing gap between measured consumption, i.e. CO_2 emissions according to type approval and real-world emissions of the vehicles. These studies also show that there is a range of factors which have served to further increase this gap over the years.

The present study examines how large the difference is regarding consumption and CO_2 emissions, between real-world consumption and type approvals in Austria’s new cars. To this end the consumption figures stated by the manufacturers of the 30 models with the most new registrations between 2000 and 2013 were compared to their real-world consumption data. The manufacturers’ data was taken directly out of their sales brochures or was based on internet databases. The real-world consumption data were based on the database “spritmonitor.de”, a publicly available database with most data entered by private users. Both data sources are subject to inaccuracies regarding exact model specifications and features (e.g. automatic transmission, air conditioning, etc.) or regarding data input. The results were therefore compared with international studies, as well as with specifications of emission calculation models and with the Austrian Air Emission Inventory (*Österreichische Luftschadstoffinventur*) – and for the most part, they correspond.

Divergence in consumption

The divergence between the official consumption data for vehicles and real-world consumption has significantly increased: In 2000 the difference between test results and real-world consumption of the models with the most new registrations was 7%. By 2013 the gap had widened to 27%.

The reason for this divergence is the driving cycles which need to be performed for the consumption tests. These cycles inadequately reflect real-world driving behaviour (especially acceleration and maximum speed) and, higher engine loads are inter alia hardly examined in the present tests. Other influencing factors such as low temperatures are not taken into consideration. In addition to the lack of real-world driving conditions, modern vehicles have electronic engine control systems which enable the vehicle to adapt to the test cycle and help the car to achieve low consumption and emission values, which partially are exceeded by real-world driving values by far. This adaptation is permissible according to the applicable legal provisions.

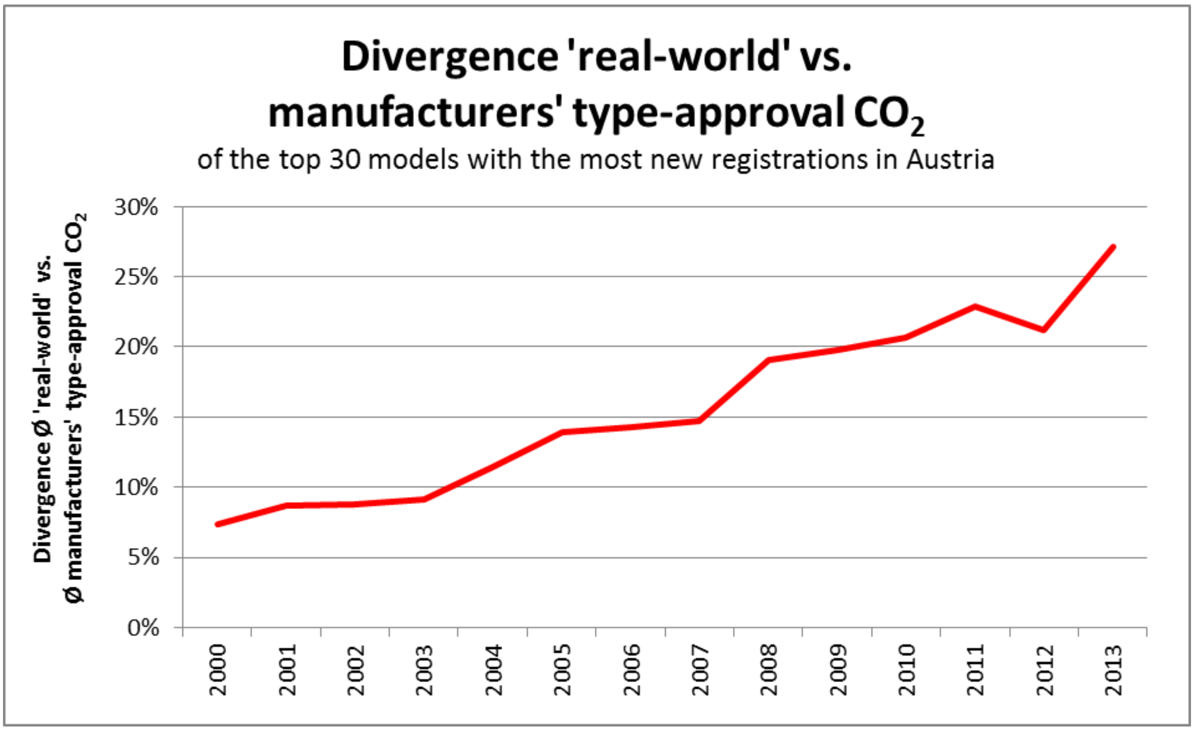

Figure 1: Development of average divergence between 'real-world' and manufacturers' type-approval of the 30 models with the most new registrations per year

Divergences in NOx emissions

There are also divergences between nitrogen oxide emissions of the official test figures of passenger cars and real-world driving figures. The Austrian immission limits for nitrogen dioxide (NO_2) valid since 2010 cannot be met at many measurement points close to traffic. Measurements from recent years show that NO_x emissions and their concentration in the ambient air have not decreased to the extent originally expected due to exhaust gas legislation. The reason for this is inter alia the divergence between emission limits and test results obtained under laboratory conditions and emissions in real-world driving.

Current test methods sometimes bring about high divergences in consumption data, which results in a decrease of consumers' faith in such data and unforeseeable additional operational costs. Additional greenhouse gases and pollutants are emitted, causing, for instance, the national maximum emission limits to be exceeded.

As a solution for this situation we recommend a rapid introduction of adequate test methods, which realistically reflect real-world fuel consumption. The introduction of more realistic test methods is currently planned for 2017; however, detailed designs for the testing procedures have not yet been set. Political decision makers and car manufacturers are called upon to make sure that test conditions are introduced which represent real-world fuel consumption and real life emissions.

2 DISCUSSION OF OVERALL SITUATION

2.1 Emissions of Transport Sector

The main sources of Austrian greenhouse gas emissions in 2013 were the following sectors: Energy and industry (45.6%), transport (28.0%), buildings (10.5%) and agriculture (9.7%). These sectors are responsible for about 95% of greenhouse gas emissions.

The transport sector shows the highest increase of greenhouse gas emissions since 1990 with a plus of 8.5 m tonnes of CO_2 equivalents or 61.4%. As well as the increase in traffic in Austria since 1990, the significant rise in greenhouse gas emissions since then has also been caused by fuel export[1] which comprised 28% of the transport sector's total greenhouse gas emissions in 2013.

The transport sector showed the biggest gap compared to its targets in the 2007 climate strategy. In 2012 greenhouse gases emitted by the transport sector exceeded by about 2.8 m tonnes the sector's target of the climate strategy. The target and the shortfall are illustrated in the following figure.

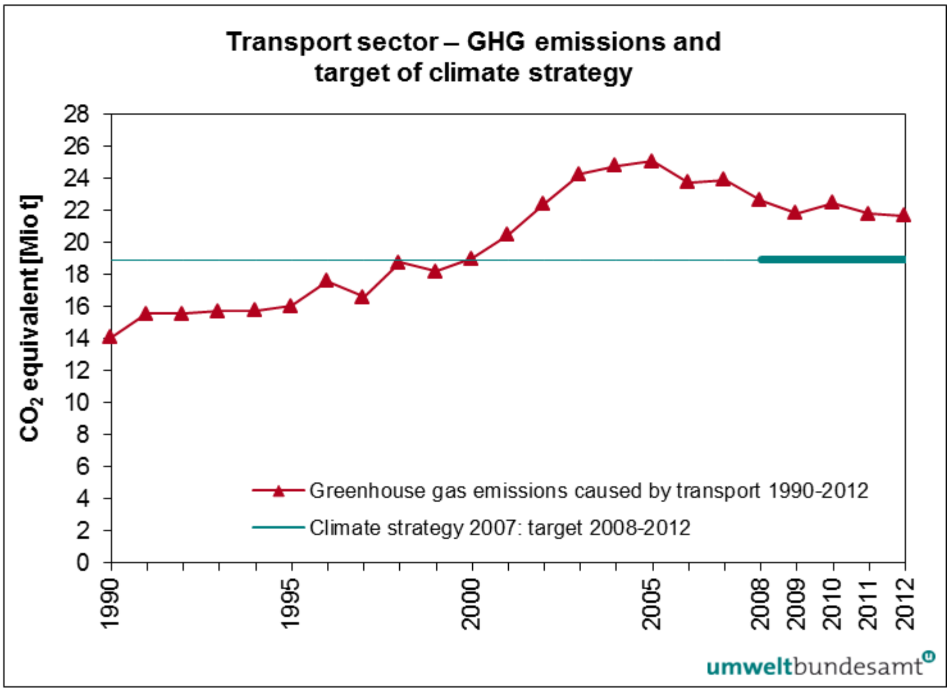

Figure 2: GHG emissions caused by the transport sector, 1990-2012 and target of the 2007 climate strategy

[1] The term 'fuel export' is used for the amount of fuel exported in car tanks, i.e. cars are refuelled in Austria, but the fuel is used in other countries, cf. Environment Agency Austria (*UMWELTBUNDESAMT*) (2015b)

Road traffic is the largest greenhouse gas source in the transport sector

Main emitter in the transport sector is road traffic whose emissions rose from 13.3 m tonnes in 1990 to about 21.8 m tonnes in 2013. Road traffic emitted about 28% of the total national greenhouse gas emissions and about 99% of the greenhouse gas emissions of the overall transport sector in 2013. The remaining 1% of all greenhouse gas emissions of the transport sector is emitted by rail, marine and national air traffic and mobile military devices.[2]

Trends show that there was a significant decrease in emissions from 2005 to 2006, which in particular was caused by a mandatory substitution of fossil fuels by biofuels according to the Austrian Fuel Regulation (*Kraftstoffverordnung*) (Federal Law Gazette part II No. 398/2012). The weak economy is primarily the reason for the reduction of emissions from 2008 to 2009. In 2010 traffic emissions rose again, especially because of an increasing demand for goods transports as a consequence of the mild recovery of the economy. The reduction of emissions in 2011 was caused by reduced fuel sales due to rising fuel prices, and the significant increase in emissions in 2013 can be explained by the significant increase in fuel sales, particularly caused by fuel export.

The following figure shows the development of greenhouse gas emissions in road traffic since 1990.

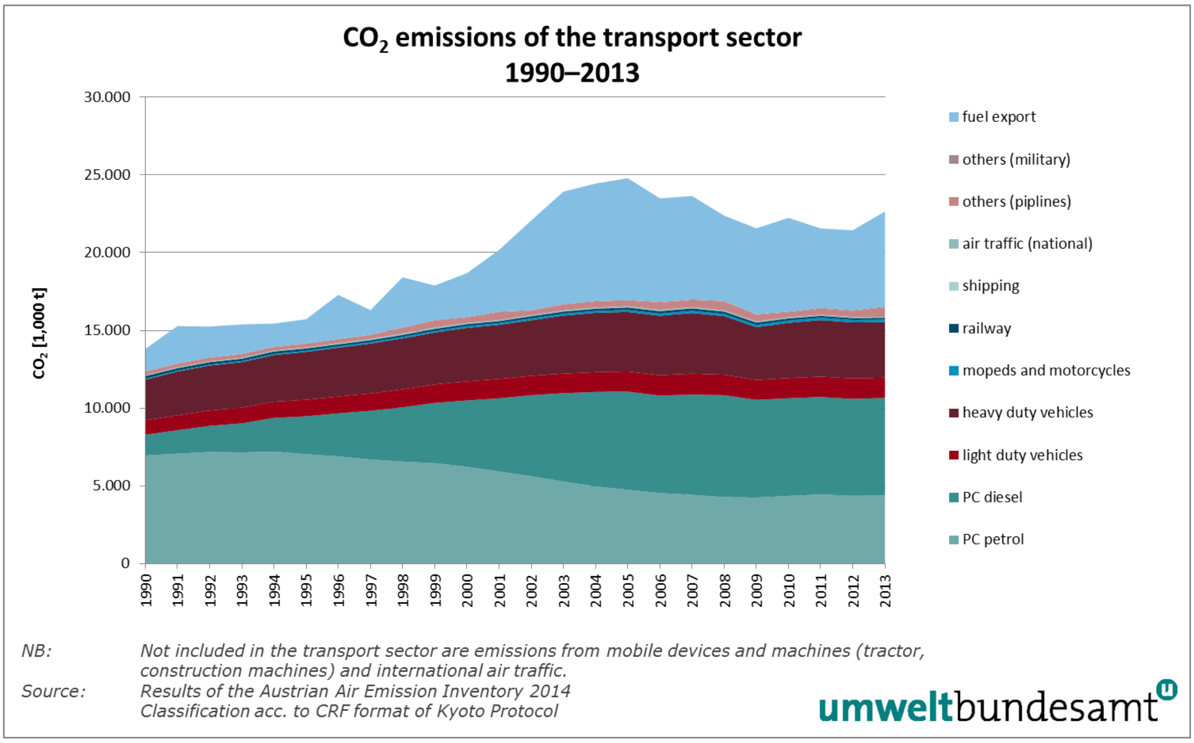

Figure 3: GHG emissions of the transport sector in Austria between 1990 and 2013

In 2013 about 45% of all greenhouse gas emissions attributed to road traffic are caused by goods transport and 54% by passenger transport. The figure below shows the permanent increase in passenger transport since 1990.

[2] cf. ENVIRONMENT AGENCY AUSTRIA (*UMWELTBUNDESAMT*) (2015b)

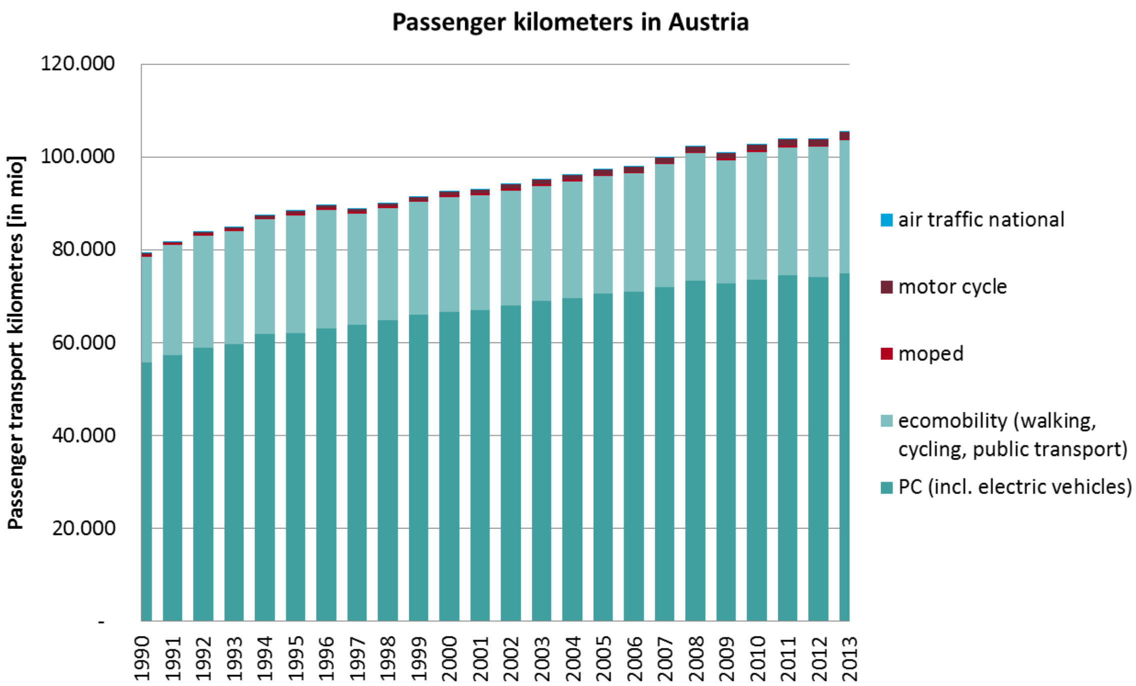

Figure 4: Development of passenger transport (Pkm) in Austria between 1990 and 2013
Source: Databases for the Austrian Air Emission Inventory 2014 (*Österr. Luftschadstoffinventur*)

2.2 Emission Factors acc. to Type Approvals – CO_2 Monitoring in Austria and Europe

2.2.1 EU Policies and Manufacturers' Targets

The Kyoto Protocol (1997) was signed by 35 industrialized countries, amongst them the then 15 EU member states. These signatories committed themselves to reducing greenhouse gas emissions by 5% - for the EU member states by 8% – compared to 1990 in the period between 2008 and 2012. Under the EU burden sharing agreement, Austria is obliged to reduce its greenhouse gas emissions by 13%.

Since passenger cars are a significant source of CO_2 emissions, in 1995 the European Commission designed a strategy to reduce CO_2 emissions from passenger cars (COM/95/689). The target for the new car fleet was set at an average value of 120 g CO_2/km (this corresponds to a consumption of 5 litres per 100 km for Otto engines and 4.5 litres per 100 km for diesel engines) for the year 2012. Since 2000 the member states have been obliged to report[3] on the CO_2 emissions of newly registered passenger cars (CO_2 monitoring).

Until now, the strategy of the Commission has been based on three core areas:

1. Voluntary agreements by the automobile industry

   One of the strategies of the Community was an environmental agreement with the automobile industry in 1998. The objective was to reduce the specific CO_2 consumption to 140 g/km by the means of technical measures by 2008/09.

[3] Decision No 1753/2000/EC of 22 June 2000 establishing a scheme to monitor the average specific CO_2 emissions from new passenger cars.

Appropriate voluntary agreements were made by the European Automobile Manufacturers Association (ACEA)[4] for 2008, by the Japanese (JAMA)[5] and by the Korean (KAMA)[6] manufacturers associations for 2009.

In the case that the targets should not be met by 2008/09, the European Commission announced a regulation with mandatory target values for CO_2 emissions from passenger cars.

2. Information on fuel consumption and specific CO_2 emissions from automobiles

   In 1999, Directive 1999/94/EC came into force. It requires information on consumption and emissions to be made available for the consumer when purchasing or leasing an automobile.[7]

3. Promotion of passenger cars with low fuel consumption by the means of fiscal measures

   In July 2002, the European Commission submitted a proposal to its member states to tax passenger cars on the basis of CO_2 emissions (COM/2002/431). In July 2005, this recommendation was emphasised in an additional document (COM/2005/261).

The evaluation of reports regarding CO_2 monitoring in the member states showed that the objective of voluntary agreements by the automobile industry was not met. Therefore the European Parliament and Council adopted Regulation (EC) No 443/2009 in December 2008, based on the proposal of the Commission (COM/2007/856). It replaces the voluntary agreements by the automobile industry with a regulation of mandatory standards. The Regulation adheres to the EU Commission's proposed objective of average CO_2 emissions of 120 g CO_2/km for new cars; however, the time frame for implementation is different.

Between 2012 and 2015 car manufacturers must reduce CO_2 emissions from new cars to an average value of 120 g/km. The target to be met is calculated for every vehicle of a manufacturer depending on the weight of the vehicle and is averaged for all approved vehicles of a manufacturer; higher (fleet) mass results in a higher target value, lower mass in a lower target value.

The Regulation requires a basis of 130 g CO_2/km to be reached by the means of improvements in vehicle motor technology, and innovative technologies. Reductions of up to 7 g/km can be taken into account achieved by so-called "eco innovations" (e.g. solar roofs, energy-saving lamps and waste heat storage), which are not considered in vehicle type approvals.

A further reduction in CO_2 emissions, necessary to meet the Union's overall objective of 120 g/km, should be reached by way of additional technical measures such as low-resistance tires, efficient air conditioning, gear shift indicators or the use of biofuels. Appropriate modalities were set out in the Implementing Regulation (EU) No 725/2011 and Regulation (EU) No 63/2011.

The target of an average of 130 g CO_2/km for the entire new car fleet within the EU needs to be fully met by 2015. As of 2012, 65% (rising to 75% in 2013, 80% in 2014, and 100% in 2015) of each

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4 ACEA members: Alfa Romeo, Alpina, Aston Martin, Audi, BMW, Bentley, Cadillac, Chevrolet, Chrysler, Citroen, Daimler, Ferrari, Fiat, Ford, General Motors, Jaguar, Jeep, Lamborghini, Lancia-Autobianchi, Land-Rover, Maserati, Mcc (Smart), Mercedes-Benz, Mini, Opel, Peugeot, Porsche, Renault, Rolls-Royce, Saab, Seat, Skoda, Opel, Volkswagen and Volvo.

5 JAMA members: Daihatsu, Honda, Isuzu, Lexus, Mazda, Mitsubishi, Nissan, Subaru, Suzuki and Toyota.

6 KAMA members: Daewoo, Hyundai, Kia and Ssang-Yyong.

7 In 2001 this Directive was transposed into national law in Austria by the "Passenger car – Consumer Information Act" (*"Personenkraftwagen-Verbraucherinformationsgesetz (Pkw-VIG)"*) act, internet platform: www.autoverbrauch.at

manufacturer's specific target value, which is defined as a function of the vehicle mass, needs to be met.

Where the specific target is exceeded between 2012 and 2015, incremental penalties for every gram of CO_2 per kilometre are due, whereby reduced penalties are set for marginal excess emissions of up to 3 g CO_2/km. From 2019 onwards, a penalty of EUR 95 is due from the first gram exceeding the target.

From 2021 onwards a maximum average CO_2 value of 95 g CO_2/km for the entire new car fleet is permitted within the EU. Between 2015 and 2021 CO_2 emissions will therefore be reduced by an additional 27%.

For smaller manufacturers producing less than 10,000 vehicles and for manufacturers of niche products with a volume of between 10,000 and 300,000 vehicles per year, the regulation holds derogations and specifically defined emission targets.

Environmentally friendly passenger cars with specific CO_2 emissions of less than 50 g/km (e. g. electric vehicles) are considered in as much as, between 2012 and 2015, as well as from 2020 onwards, they can be counted as 2 or more cars when calculating the fleet average of a manufacturer (so-called super credits). They additionally reduce the average CO_2 emissions of the vehicle fleet of a manufacturer.

2.2.2 EU Control Mechanisms and their Implementation in Austria

Decision No 1753/2000/EC establishes a scheme to monitor the average CO_2 emissions from new passenger cars in order to check compliance with the voluntary agreements by the automobile industry. Pursuant to Article 4 (4) of this Decision the required data is to be reported annually to the European Commission by the member states.[8] The number of newly registered cars, as well as the average CO_2 emissions is to be collected and transmitted. Furthermore, data is to be split into:

- Specific emissions of CO_2 (in g/km),
- Fuel type (e.g. petrol, diesel and alternative fuels),
- Manufacturer or make,
- Mass (kg),
- Net power (kW) and
- Engine capacity (in cm^3).

On 1 January 2010 the requirements regarding CO_2 monitoring were significantly extended by Regulation (EC) No 443/2009 and mandatory limits for car manufacturers were defined. The member states now have to record the following data on passenger cars newly registered in their territory and transmit the data to the European Commission by 28 February of the following year:

- Manufacturer,
- Type, variant and version,

[8] Decision No 1753/2000/EC was repealed by Regulation (EC) No 443/2009. For reasons of data consistency over the monitoring period the present report continues to process data according to the requirements of Decision No 1753/2000/EC. At the same time the Republic of Austria reports its monitoring data according to Regulation (EC) No 443/2009 to the European Commission.

- Specific emissions of CO_2 (in g/km),
- Mass (kg),
- Wheelbase (mm) and
- Track width (in mm).

Additionally every member state needs to determine for each manufacturer

a. the total number of new passenger cars registered in its territory,

b. the average specific emissions of CO_2,

c. the average mass,

d. for each version, each variant and each type of new passenger car:

   i. the total number of new passenger cars registered in its territory,

   ii. the specific emissions of CO_2 and the share of emissions reduction as a result of innovative technologies,

   iii. the mass,

   iv. the footprint of the passenger car.

The Environment Agency Austria (*Umweltbundesamt*) is responsible for the reporting on behalf of the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management.

The basis for CO_2 monitoring is the data of Statistics Austria, which is based on the new registrations of passenger cars through car insurance companies. New registrations are defined as brand-new vehicles registered for the first time in Austria. Passenger cars are exclusively cars belonging to the category M1[9].

Information on CO_2 values and average fuel consumption is primarily taken out of the Certificate of Conformity – for short: COC[10] (EU type approval) – which states the value measured in the type approval testing (NEDC[11]).

2.2.3 NEDC as a Basis for Determining CO_2 Emissions

The New European Driving Cycle (NEDC) sets the conditions under which a vehicle with a combustion engine needs to be operated when fuel consumption and thus CO_2 emissions are determined. The result of the consumption test according to the NEDC is entered into the Certificate of Conformity of a vehicle and describes the “official” fuel consumption.

The NEDC goes back to the end of the 1960s when Germany and France decided on exhaust standards for the first time which resulted in the common driving cycle of the Directive 70/220/EEC

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[9] Category M: Motor vehicles designed and constructed for the carriage of passengers with at least four wheels and a maximum weight not exceeding 2.6 t, as well as vehicles designed and constructed for the carriage of passengers with at least three wheels and a permissible mass of more than 1 t; Category M1: Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver’s seat.

[10] Certificate of Conformity; basically corresponds to vehicle registration certificate. The COC confirms that the new vehicle met the EU type approval for this vehicle at the time of delivery. An EU type approval is mandatory for new vehicle types from 1997 onwards.

[11] NEDC – New European Driving Cycle; driving cycle used in the type test for determining consumption and exhaust emissions

of March 1970. As a result of the oil crisis, a first method to measure fuel consumption designed by the United Nations Economic Commission for Europe followed in 1976, which was transposed into DIN standard 70030 in 1978. This driving cycle already comprised a simulation of urban traffic and consistent speeds of 90km/h and 120km/h, coming very close to the test cycle which still is in use nowadays.

In 1992 the simulation of urban traffic based on DIN standard 70030 was finally transposed into Directive 70/220/EEC marking the beginning of the NEDC. Since 1997 the emission standard determined in the NEDC needs to be taken as a basis for calculating fuel consumption. Emission standard EURO III added the cold-start element to the NEDC: The measurement of the car, which is pre-heated to approx. 25°C starts immediately and not after 40 seconds, as previously the case. With the introduction of the exhaust standard EURO 5, Directive 70/220/EEC was repealed by Regulation 715/2007. It was recommended to review the driving cycle, however, it still is in use.

For determining consumption of a vehicle, first of all rolling and air resistance on the road are identified by the means of a roller test bench. Then the vehicle is parked at an ambient air temperature of 20°C to 30°C. After six hours it undergoes the actual test cycle which lasts 1180 seconds, i.e. about 20 minutes, in which two thirds of the time urban conditions are simulated and one third extra-urban conditions at an average speed of 33.6km/h and with the gear positioned in neutral for about 23.7% of the time (cf. Fig. 5). The CO_2 emissions measured in this test are then converted into fuel consumption and entered into the COC of the respective vehicle.

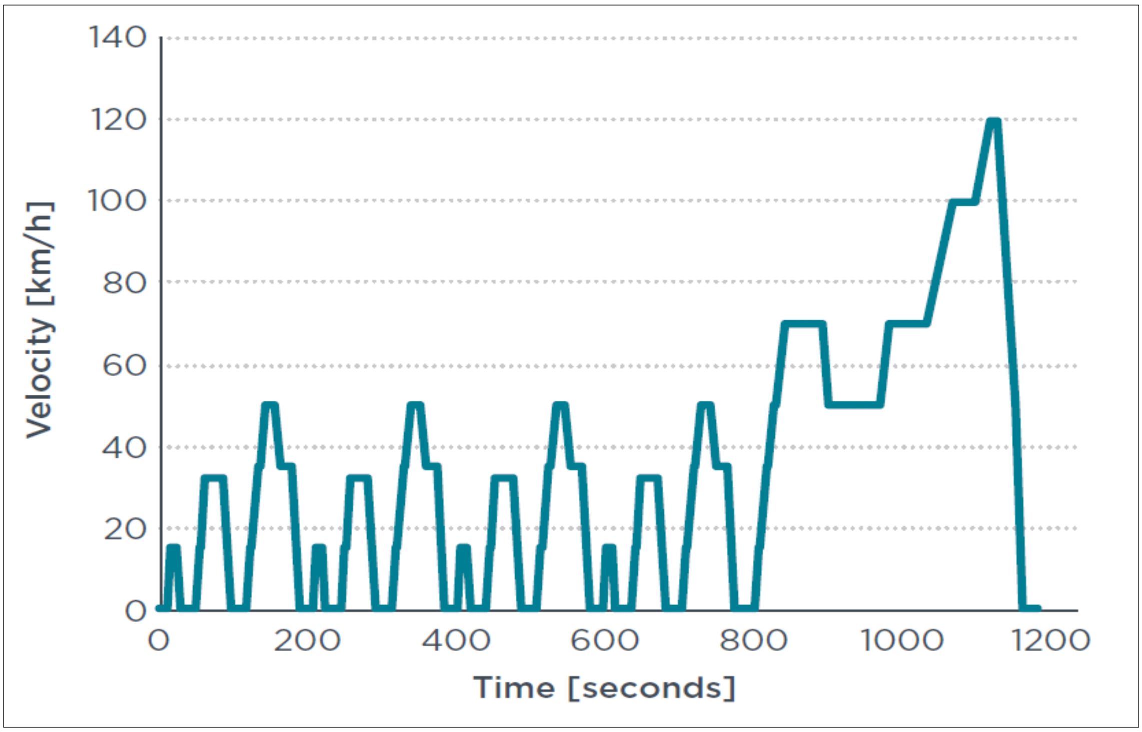

Figure 5: NEDC according to Directive 70/220/EEC, source: (ICCT 2014b)

The basis from which the NEDC was developed was actually not meant to determine the fuel consumption of a vehicle, but its emitted airborne pollutants. The NEDC, however, was and is still used today for exactly this purpose. The benefit of a standardised test cycle in a laboratory is its repeatability and easy comparability of the test results.

However, there are many disadvantages of the NEDC, which result in consumption figures not reflecting consumption in real-world driving. The driving cycle does not, for instance, reproduce real-world driving behaviour, since velocities beyond 120 km/h are not recorded and unrealistically low acceleration behaviour is applied. Furthermore, only a few requirements are defined for the manufacturers, leading to them optimising the vehicles regarding CO_2 emissions on the test bench and not reflecting emission behaviour of the production vehicle during road use. Examples of this optimisation are:

- Overinflating the tyres to reduce rolling resistance
- Taping over indentations or protrusions on the body to reduce aerodynamic drag
- Disconnecting the alternator
- Altering wheel alignment and camber inclinations
- Minimising vehicle weight
- Optimising the engine map

2.2.4 Development of CO_2 Emissions according to the NEDC in Austria and Europe

The progress of the manufacturers in reducing CO_2 emissions according to the NEDC is recorded by the member states and annually reported to the European Commission on a pan-European level.

For the year 2014 an emission factor of 123.4g CO_2/km (T&E 2015) was determined by averaging the results of the overall European new car fleet of the 15 best-selling manufacturers. This means, that on average, manufacturers have already met and exceeded the 130g CO_2/km limit of the European Commission for 2015. The reduction of about 2.7% compared to the previous year (2013: 126.8g CO_2/km) is significantly lower than in 2013 (4.1%) and also below the average reduction of 3.6% between 2007 and 2014. The reasons why they were below the target ahead of schedule are not only the technological developments, but also the improved possibility of the manufacturers to adjust the vehicles to the driving cycle.

A comparison of the 15 manufacturers with the most new registrations (BMW, Daimler, Fiat, Ford, General Motors, Honda, Hyundai, Mazda, Nissan, Peugeot-Citroen, Renault, Suzuki, Toyota, Volkswagen and Volvo) shows a heterogeneous picture; the lowest emission factor is achieved by Peugeot-Citroen, whose newly registered vehicles emit, on average, 110.1g CO_2/km according to the NEDC. At the other end of the list is Honda with an average emission factor of 133.9g CO_2/km for all newly registered vehicles.

Nissan had the biggest reduction compared to the previous year with 12.1%, which is primarily due to many model updates and developments in their range of different engines. According to the analysed data, the emission factors of newly registered vehicles deteriorated among Ford vehicles (from 121.6g CO_2/km to 121.7g CO_2/km, i.e. +0.1g) and Hyundai vehicles (from 130.0g CO_2/km to 130.5g CO_2/km, i.e. +0.5g).

The average limit of the European Commission of 130g CO_2/km in 2015 is calculated on a manufacturer level and subject to the average fleet mass with the following formula:

$$\mathbf{CO_2 = 130 + a \times (M - M0)}$$

M_0 … reference mass (basic value from 2006 of EU overall fleet), 1.372 kg
M … average mass of a manufacturer’s fleet / pool
a … slope of the straight line; 0.0457

The conclusion is that the manufacturers with the lowest emission factors are not necessarily the ones who most clearly exceeded their targets. The respective analysis for the year 2014 shows that all manufacturers, except Honda, Hyundai and Suzuki, already fulfilled their targets for 2015 in 2014 (cf. Fig.6). Regarding the target of 95g CO_2 in 2021, an assumption based on the development rates of previous years shows that the manufacturers Fiat, General Motors, Honda, Hyundai, Mazda and Suzuki need to accelerate their development in order to be able to meet their manufacturer targets.

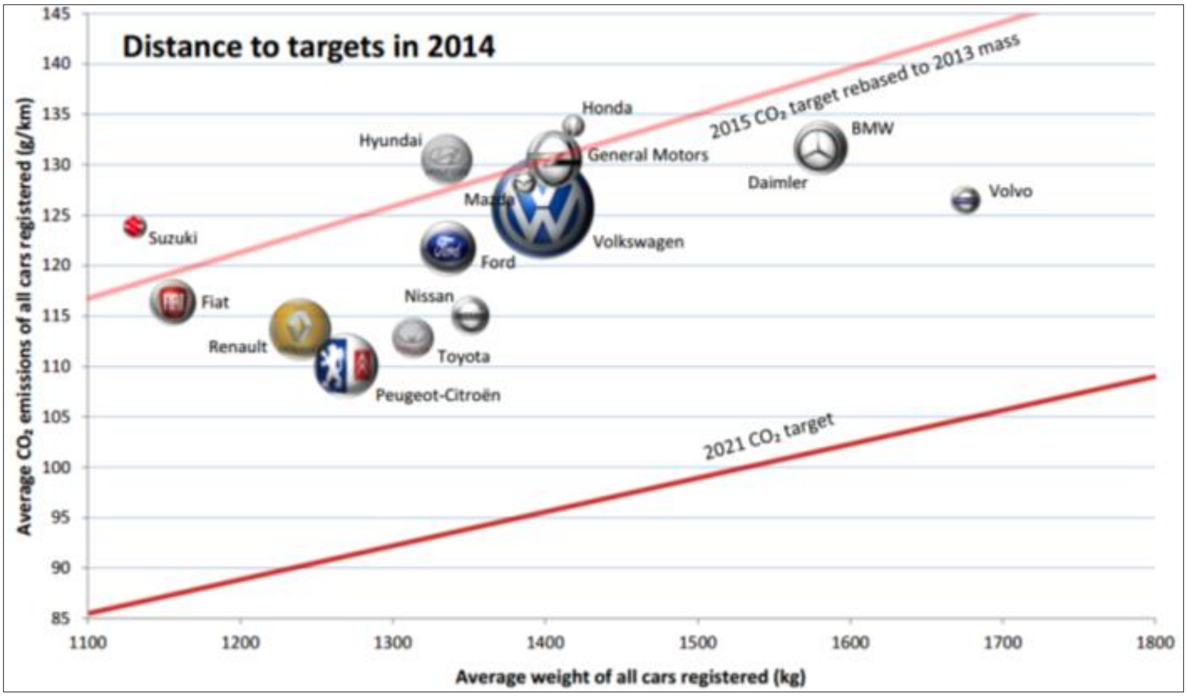

Figure 6: CO_2 emissions in 2014 ranked according to manufacturers with regards to EU target lines 2015 and 2021 for the overall European passenger car fleet (Source: T&E 2015)

In Austria the progress of the manufacturers in reducing CO_2 emissions according to NEDC is annually analysed and published by the Environment Agency Austria (*Umweltbundesamt*) on behalf of the Federal Ministry of Agriculture, Forestry, Environment and Water Management.

In 2013 the average emission factor was 131.5g CO_2/km for approx. 317,000 newly registered diesel and petrol-powered passenger cars (diesel: 134g CO_2/km, petrol: 129g CO_2/km) (Environment Agency Austria, UBA 2014). Figure 7 shows that this value is beyond the respective European average, as in the years before, which is due to the comparably big share of high-performance and heavy passenger cars in Austria. From today's point of view, meeting the European Commission's limit of 130g CO_2/km in 2015 does, however, also seem likely for the Austrian fleet. The reduction on last year (2012: 136.2g CO_2/km) is about 3.5% and complies with the long-term average of 3.5% between 2007 and 2013.

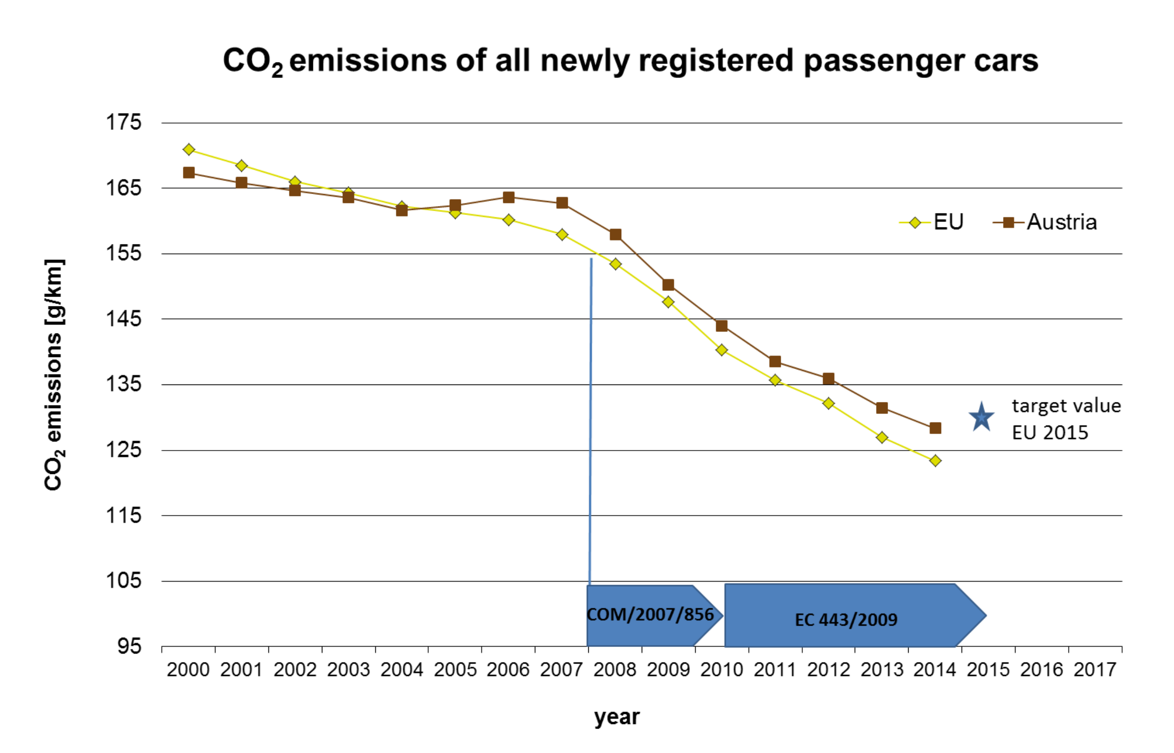

Figure 7: Development of CO_2 emissions according to the NEDC in Austria and Europe (author's diagram)

A comparison of all manufacturers represented in Austria in 2013 with more than 1,000 new cars shows that the majority of the manufacturers were below their limit for 2015 already in 2013 at a target achievement rate of 100%. Top of the list is Renault with an average emission factor of 114.2g CO_2/km (with a target of 133.10g CO_2/km). The manufacturers Dacia, Fiat Group, General Motors Company, Honda, Hyundai and Suzuki need to do more development work, with Suzuki being farthest away from its specific target (by 16.6g CO_2/km).

A comparison of the 15 makes with the most new registrations in Austria (Audi, BMW, Citroen, Fiat, Ford, Hyundai, Mazda, Mercedes, Opel, Peugeot, Renault, Skoda, Suzuki, Toyota and Volkswagen) shows a gap of 30.2g CO_2/km between the lowest and the highest emission value. Again, the list is topped by Renault with 113.1g CO_2/km. Last is Mercedes with 143.3g CO_2/km. Renault also shows the biggest reduction of CO_2 emissions compared to the previous year with about 10%. Mercedes also has an above average reduction of about 4.9%. Fiat, however, shows a reduction of only about 0.8%.

2.3 Divergences between Type Approvals and Real-World Consumption

The CO_2 emissions of a vehicle are in direct relation to its fuel consumption. Therefore, the CO_2 emissions measured according to the NEDC are converted into fuel consumption, which is one of the primary decision criteria when people buy a car. Since CO_2 emissions are determined under unrealistic driving conditions, as described above, the fuel consumption stated by the manufacturers does not comply with figures observed in real-world driving. This chapter discusses the divergence between indices according to type approvals and the measured values in real-world driving.

The following figure 8 shows a comparison of different test cycles. The diagram shows the velocities which are applied during a given time period. The blue line shows the results of the NEDC and the red line shows the results of the so-called CADC, a test cycle which shows results closer to reality. The diagram clearly shows that the NEDC has a significantly lower speed level, reaches a lower maximum speed (for a very short duration 120 km/h), has more standing times and shows significantly lower dynamics.

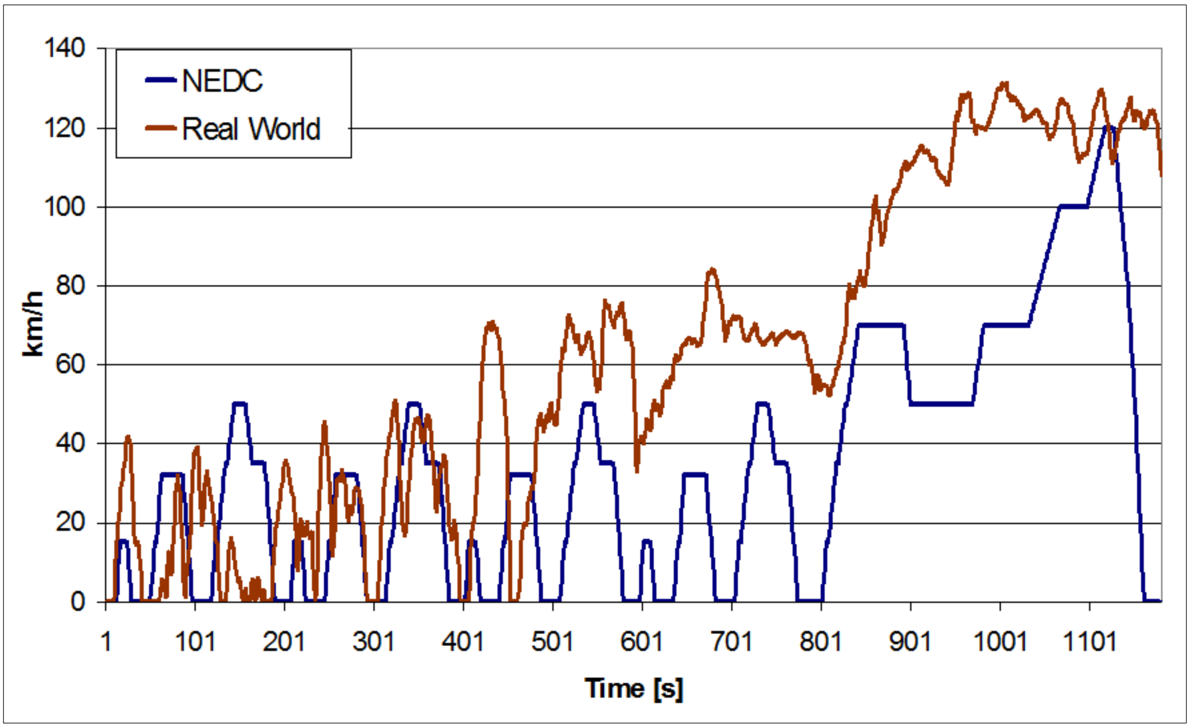

Figure 8: Type approval testing passenger cars compared to real-world driving (CADC)[12]

The CADC (Common Artemis Driving Cycle) was developed during the ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems in the fifth EU research programme) project. The ARTEMIS test cycle has a driving dynamics and engine performance closer to reality and is characterised by later gear-change points and significantly higher engine speed than the NEDC (New European Driving Cycle), which is used for type approvals. The CADC allows for a display of emission behaviour significantly closer to reality. Thus the CADC consumption values and emission factors significantly deviate from NEDC values.

2.3.1 Trend Description of Divergence in Europe

The divergence between type approvals and real-world driving has reached such a dimension in recent years that several organisations have more intensively taken up this topic, even those which do not have traffic or mobility as one of their core competences. Thus there are already many publications which discuss to a different extent the lack of a greening effect and the deception of consumers, e.g. publications by Transport & Environment, by the BEUC, the European Consumer

[12] HAUSBERGER, S. (2011)

Organisation, by ANEC, the European consumer voice in standardisation or by national automobile clubs. What most of these publications have in common is that they are all based on the papers of the International Council on Clean Transport (ICCT). The following analyses are also based on ICCT papers from the year 2013 (ICCT 2013) including updates from 2014 (ICCT 2014).

Due to binding regulations by the European Commission, CO_2 emissions from passenger cars could significantly be decreased in recent years. Some manufacturers have even met and exceeded the binding targets for 2015 ahead of schedule, although the emission figures are, as mentioned before, measured by means of a test cycle called the New European Driving Cycle (NEDC), which does not apply real-world driving conditions. Calculating the divergence between emission figures according to the NEDC and real-world driving figures presumes the definition of an unambiguous real-world driving condition, or one driving profile. This, however, is not possible, since all drivers have their own individual driving profile. Instead of using such a definition in its studies, the ICCT analysed big data collections on real-world fuel consumption by the means of statistic methods and thus was able to quantify the divergences. The basis for the analyses was eight different data sources from Germany, Great Britain, France and Switzerland covering the years 2001 to 2013. A total of approx. 540,000 vehicle data sets were available for their analyses.

Source	Country	Total number of vehicles in database	Number of database entries per year(rounded)	Primarily company cars
spritmonitor.de	Germany	85,666[13]	6,000	
Travelcard	Netherlands	311,611	20,000	X
LeasePlan	Germany	90,000	15,000	X
honestjohn.co.uk	Great Britain	50,332	3,500	
AUTO BILD	Germany	1,978	250	
Auto Motor Sport	Germany	1,660	150	
WhatCar?	Great Britain	284	150	
TCS	Switzerland	332	20	
Sum total		541,863	45,000	

Table 1: Summary of data sources from (ICCT 2014)

The compilation of results show an inhomogeneous image with regards to the relative divergences between CO_2 emissions from real-world driving and those from type approvals according to the NEDC. In 2000 real-world CO_2 emissions exceeded type approval emissions in all data sources going back to this year by a similar range, i.e. between 8% and 10%.

In 2013 this range was already between 20% and 50%, depending on the database used for analytic purposes. All data sources, however, have one thing in common: The strong, partially exponential increase in divergences in the previous decade. The authors of the study created divergence curves for private cars, company cars and the total of all vehicles weighted according to the number of analysed data sets, and thus calculated the average exceedance of emission factors according to type approvals of 31% (private cars), 45% (company cars) and 38% (Ø of all data sources) in real-world driving for the year 2013.

[13] As of 7 October 2015: 276,000 passenger cars

Divergences of company cars are higher, since the fuel costs are usually paid by the company and thus the incentive to drive in an economic way is lower than for private persons. Additionally, it can be presumed that drivers of company cars drive more dynamically with higher average fuel consumption due to time pressure.

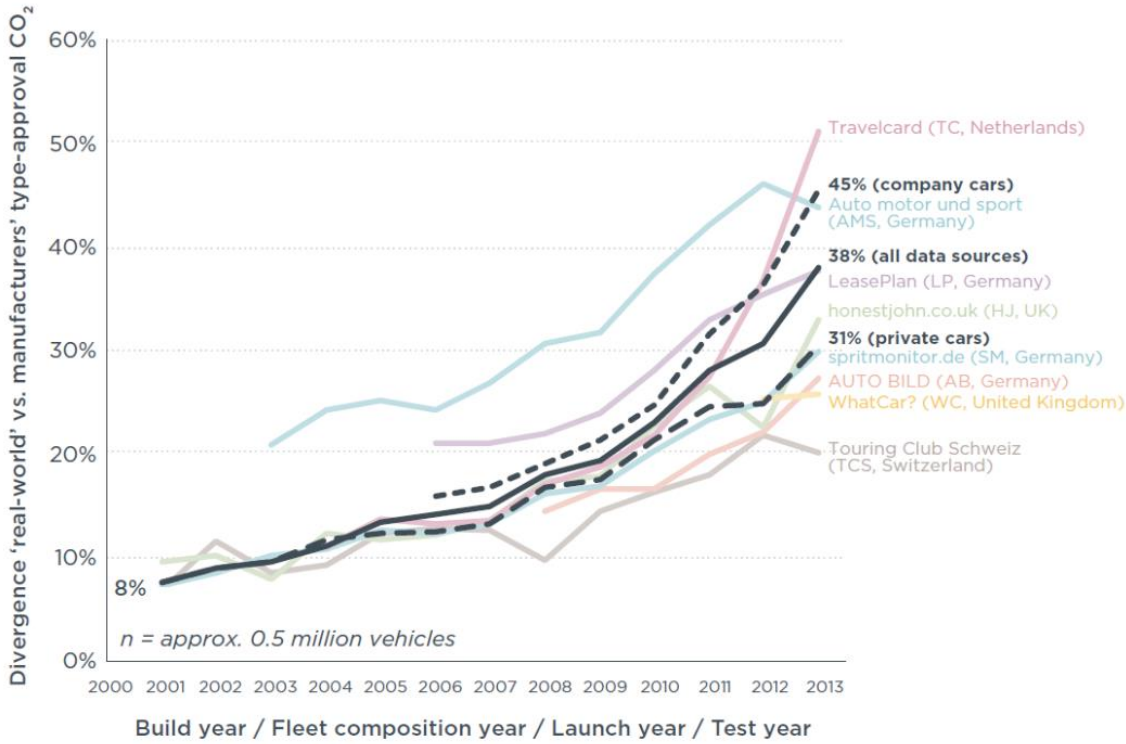

Figure 9: Divergence between type approval and real-world CO_2 emissions of different data sources including calculated average values for private and company cars and for all data sources

If an average emission factor of 126.8g CO_2/km (or the equivalent of fuel consumption of 5.11 l/100km) according to the NEDC is taken as a basis for the entire European fleet of passenger cars in 2013 (T&E 2015), real emission factors of up to 183.9g CO_2/km (company cars) or real-world fuel consumption of up to 7.41 l/100km[14] can be calculated.

[14] Assumption: Equal distribution of petrol and diesel-powered vehicles

Vehicle category	Ø CO_2 emissions for entire European passenger car fleet (T&E 2015) [g CO2/km]	Ø Fuel consumption for entire European passenger car fleet [l/100km]	Relative exceedance of CO_2 emissions according to type approvals under real-world driving conditions (ICCT 2014) [%]	Ø CO_2 emissions under real-world driving conditions [g CO_2/km]	Ø Real-world fuel consumption [l/100km]
Private vehicles			31	166.1	6.69
Company vehicles	126.8	5.11	45	183.9	7.41
All vehicles			38	175.0	7.05

Table 2: Compilation of divergences between type approvals and real-world driving on fleet level (ICCT 2014, complemented by own calculations by the authors)

A detailed analysis on vehicle category and manufacturer level was conducted for data sources spritmonitor.de, Travelcard and LeasePlan. The fleet composition of Travelcard, however, is a consequence of taxation of company cars, which is not representative for Austria. This is the reason why the following analyses were carried out based on the data source spritmonitor.de (representative for private vehicles) and based on data by Travelcard (representative for company vehicles).

The distribution of the newly registered vehicles recorded in the database of spritmonitor.de reflects the entire German vehicle fleet quite well with an average NEDC emission factor of 145g CO_2/km for the year 2011 (reported emission factor of 146g CO_2/km according to CO_2 monitoring Germany for 2011).

The divergence between CO_2 emission results according to type approvals and those under real-world driving conditions is approx. 30% for 2013. Hybrid vehicles show an excess emissions of 39%, which is on the one hand a result of the technology of this type of car, and on the other hand a consequence of the automatic transmission which is built into all hybrid cars. The analysis of all vehicles with automatic transmission showed excess emissions of 36%.

The analysis of the database spritmonitor.de on the vehicle category level shows that very small vehicles are below average with average excess emissions of 24% in 2013. Small vehicles (27%), as well as lower middle-class vehicles (31%), which comprise almost half of all vehicles in the database, and to a lesser extent also middle-class cars (35%) are well depicted. In the upper middle class, however, relative CO_2 excess emissions according to the NEDC compared to real-world driving conditions amount to 45% and the sports cars class (39%) also lies above average.

As a consequence, the excess emissions of the manufacturers producing vehicles with a comparatively low average weight are also below average (Fiat, Peugeot and Renault-Nissan at 26%) and Daimler, for instance, is clearly above average with 38%. The analysis of the Volkswagen Group, which comprises almost half of all vehicles in the database, shows that the group as a whole falls short of the average with 28%. Analysing Audi alone, however, shows excess emissions under real-world driving conditions of 39%. Toyota, on the other hand, is a special case: Due to the number of small and lower middle-class cars Toyota produces its excess emission clearly below average with 25%. If the hybrid cars, however, are analysed alone, average excess emissions increase (e.g. for Auris hybrid and Yaris hybrid) to 37% in 2013.

LeasePlan's database differs from spritmonitor.de in so far that divergences between CO_2 emissions from the type approvals and from real-world driving cannot be calculated for a specific year of newly registered cars, but only as average value for a year of analysis. The fleet analysed for a specific year therefore also comprises older vehicles and not only the ones which were newly registered in the respective year. Due to this fact, the average excess emissions of 38% calculated for 2013 may be even higher for newly registered cars in that year. The distribution of vehicles in LeasePlan's database with an average emission factor of 140g CO_2/km in 2011 does not reflect the entire German vehicle fleet (reported emission factor of 146g CO_2/km in the same year) as accurately as spritmonitor.de. This is especially due to the fact that this database only includes diesel vehicles, which show a general tendency to emit less CO_2 than petrol-powered cars. The distributions of vehicle categories and manufacturers are also not representative for the entire German fleet (ICCT 2013).

However, the analysis of the LeasePlan data confirms the trend of an increasing divergence between CO_2 emissions according to NEDC and real-world driving CO_2 emissions observed in the analysis of the data source spritmonitor.de. As such, the average excess emissions rose by 5% within 2 years (2011: 34%). An increase (with a range between 3% and 8%) was calculated in all vehicle categories and with all manufacturers (the only exception being Fiat). According to the analyses of the study authors, the LeasePlan database shows an above-average divergence for small vehicles and upper middle-class cars, as well as cars made by Audi, Daimler, Ford, General Motors and Toyota.

Different data sources use different methods for the collection of their data and also differ in the compilation of the fleet, driving situations, driving behaviour and topographic and climatic conditions. Therefore it is to be expected that there are divergences in the analysed data and the analysed results. However, all data sources confirm that there has been a trend towards a clear increase of divergence between the CO_2 emissions calculated according to the New European Driving Cycle and those observed in real-world driving in recent years. An analysis using examples from the database spritmonitor.de calculates real-world average CO_2 emissions for the year 2013 to be 165g CO_2/km, which is 38g CO_2/km more than according to the type approvals (cf. Fig. 10). This translates into real-world fuel consumption of 6.65 l/100km instead of 5.42 l/100km[15].

[15] Assumption: Equal distribution of petrol and diesel-powered vehicles

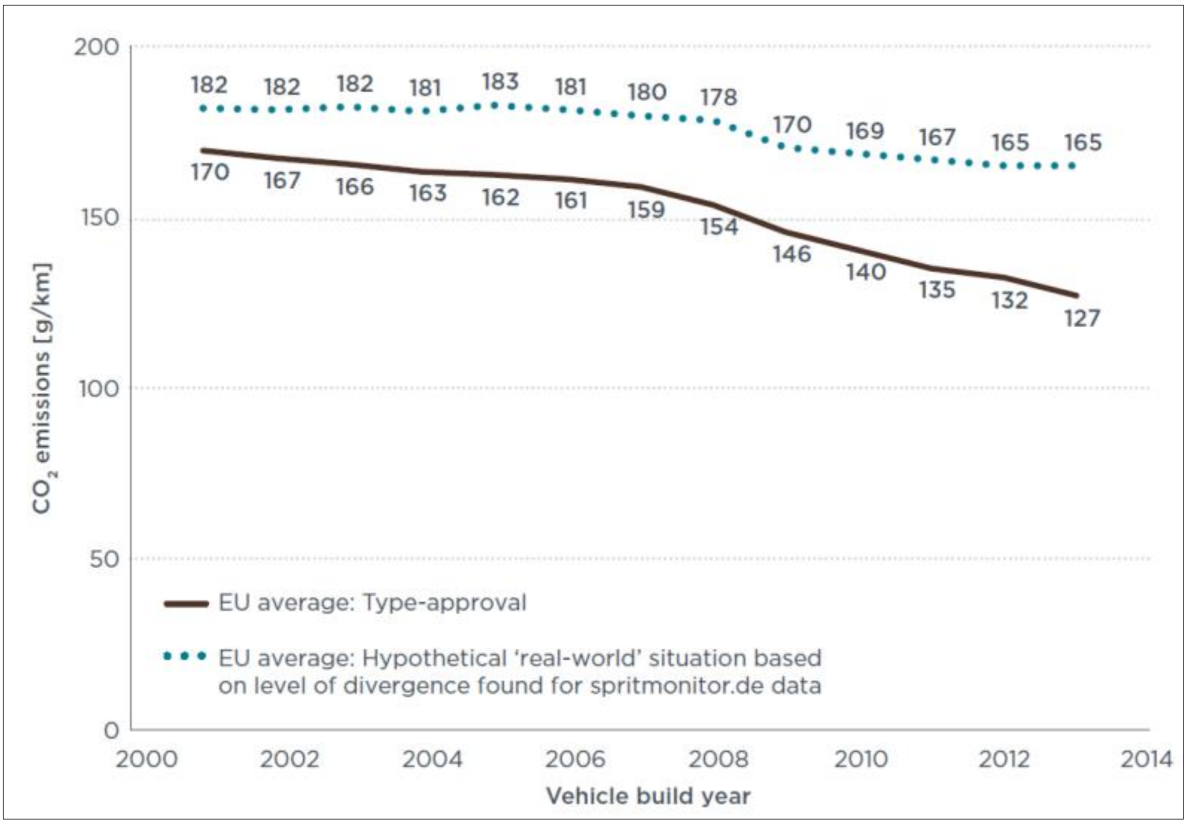

Figure 10: Development of CO_2 emissions according to type approvals, and from real-world driving using examples of the database spritmonitor.de for the years 2001 to 2013

The study authors from the International Council on Clean Transportation state three factors which in combination are responsible for the aforementioned divergence and its constant increase.

1. Technology: Alternative motor technologies such as the electric engine in hybrid vehicles or technological developments such as the very often built-in automatic stop-start have the effect of reducing fuel consumption to a great extent in the test cycle.
2. Test cycle: The New European Driving Cycle is characterised by much flexibility and insufficient definition, as described above. This is increasingly exhausted to the limits by the manufacturers in the test procedure in order to reduce theoretical fuel consumption.
3. External parameters: Many developments made to the vehicle happen as a result of changing times. Air conditioning, for instance, is built into almost all new cars. Deactivating it during the test procedure is permitted and reduces fuel consumption, as well.

2.3.2 The WLTP as a Reaction to Increasing Divergence

If CO_2 emissions continue to be measured using the NEDC, a further increase in divergence between CO_2 emissions according to type approvals and CO_2 emissions from real-world driving is to be expected. This increasing divergence has a negative impact on the persons who want to buy a car, since they see themselves confronted with higher fuel costs; on national governments, since this means less tax income for car registrations; and on manufacturers, since they lose their credibility in their consumers' eyes; plus the results with regards to achieving the EU target of reducing CO_2 emissions are also distorted.

The European Union decided to replace the NEDC with the Worldwide Harmonized Light Vehicle Test Procedure (WLTP) for measuring CO_2 emissions in order to counteract these developments. The first meeting of the United Nations WLTP Working Group in June 2008 initiated the work on the test procedure, which should be completed in September 2017 by the implementation of the WLTP as binding procedure for measuring CO_2 emissions from Euro class 6c onwards. The transition from NEDC to the driving cycle of the WLTP, the Worldwide Harmonized Light Vehicle Test Cycle (WLTC), has an impact on existing CO_2 fleet targets (e.g. the binding EU limit of 95g CO_2/km in 2021) and CO_2 based taxes. Thus special attention is given to the development of so-called correlation factors for converting between test cycles.

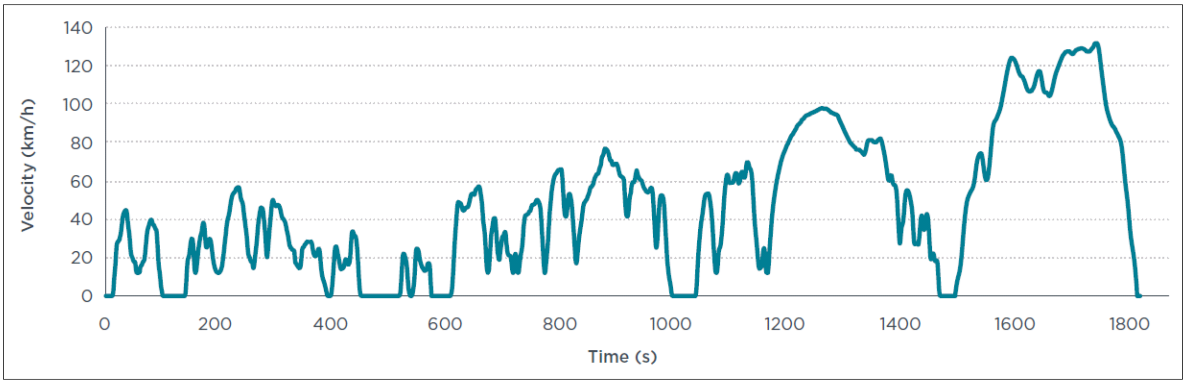

Figure 11: WLTP test cycle (WLTC), Source: (ICCT 2014b)

WLTP's objective is to represent as accurately as possible real-world driving behaviour under laboratory conditions. Thus it significantly differs from NEDC in some parameters. The following table shows a list of selected parameters as a comparison of the test cycles. The stop-start systems, for instance will show less reduction of fuel consumption as in the NEDC today due to a smaller share of standstill periods. The average speed is higher in general and the entire test cycle is more dynamic, as well. Just like in the NEDC, HVAC - Heating, Ventilation and Air Conditioning systems are not taken into account during the test.

Nevertheless, a first test series of the German inspection organisation TÜV SÜD (Technical Inspection Association) in a comparison of both test cycles, NEDC and WLTC in the spring 2015 showed that especially the test results of CO_2 emissions (and thus fuel consumption) of WLTC were partially even below the ones of the NEDC tests (TÜV 2015). If the testing procedure of the Worldwide Harmonized Light Vehicle Test Cycle really provides more realistic testing results, will probably remain to be seen after detailed technical frame conditions will have been set and implemented in the autumn 2017.

	Unit	NEDC	WLTC
Duration of cycle	[sec]	1180	1800
Length of cycle	[km]	11.03	23.27
Average speed	[km/h]	33.6	46.5
Maximum speed	[km/h]	120.0	131.3
Neutral share	[%]	23.7	12.6
Constant drive share	[%]	40.3	3.7
Acceleration share	[%]	20.9	43.8
Deceleration share	[%]	15.1	39.9

Table 3: Divergence between NEDC and WLTC (ICCT 2014b)

2.4 Air Emission Inventory against the Background of Divergence

The following chapter describes how the Austrian Emission Inventory takes account of the fact that there is a big (from an environmental point of view - negative) divergence between the legally mandatory type approval and real-world emissions. First the methodology of inventory in road traffic will be described, then the source of emission factors in road traffic, and finally it will be explained how real emission factors are displayed in the calculation methodology.

This study analyses real-world consumption data provided by “Spritmonitor” for the models with the most new registrations. Their average consumption data is the basis for the calculation of total emissions of passenger car traffic. Attention was paid to clearly allocate the different data to the specific models (in any case year, engine variant and power output, depending on available information also gear variant and body).

The comparison of the overall results with the results of the Austrian Air Emission Inventory (*Österr. Luftschadstoffinventur*) is taken as a comparison of the calculation results and for plausibility purposes.

Methodology of inventory (road traffic)

The Austrian Air Emission Inventory (*Österr. Luftschadstoffinventur*) in the transport sector is calculated with the simulation program NEMO (Network Emission Model). NEMO was developed at the Institute of Internal Combustion Engines and Thermodynamics at Graz University of Technology for calculating emissions and fuel consumption in traffic networks using state-of-the-art scientific methods.[16] The methods and functionalities are briefly described below.

Accounting is carried out annually over freely selectable calculation periods. NEMO combines a detailed calculation of the compilation of the vehicle fleet with a detailed consumption and emission simulation per vehicle. In a first step, NEMO calculates the compilation of the domestic fleet according to the share of number of vehicles in use and the share of vehicle kilometres. The fleet is divided into so-called “vehicle classes”, subdivisions based on statistics on the number of vehicles and according to emission and consumption-relevant criteria.

Model input data

- Vehicle category (e. g. passenger car, light-duty vehicle, solo lorry, ...)

16 DIPPOLD/REXEIS/HAUSBERGER (2012)

- Type of drive (e. g. Otto engine, diesel engine, electric drive)
- Size class (distinctive feature e. g. engine capacity or maximum permissible weight)
- Technology class (usually according to the law based on which the vehicle was registered for the first time, and where applicable, in combination with the technology used, e.g. HDV: EURO V with SCR)
- Additionally (retrofitted) exhaust after-treatment systems (e.g. particle oxidation catalyst)
- Fuel used
- Specific energy consumption of the vehicles (petrol, diesel or electric energy per vehicle kilometre or kilometre per person or tonne),
- Specific emission factors
- Specific annual mileage

Model output data

- Overall annual mileage
- Overall energy consumption of road traffic
- Overall emissions of passenger car fleet; the greenhouse gases CO_2, CH_4, N_2O as well as all common air pollutants (NO_x, particulate matter, SO_2, NMVOC etc.) and evaporative emissions are calculated.
- Transport performance (kilometres per person and tonne)

The NEMO model uses emission factors from the Handbook Emission Factors for Road Transport (HBEFA) for calculating emissions of road traffic. The main subject of HBEFA is emission measurements of passenger cars in real-world driving, and driving behaviour analyses.

Handbook Emission Factors Road Transport (HBEFA)

This handbook was commissioned by the environment agencies of Switzerland, Austria and Germany in the 1990s, since "information on specific emissions are needed, i.e. on emissions of individual vehicles"[17] in order to determine the extent, development trend and potential reduction of traffic-related emissions. By now the Handbook/HBEFA group is supported by more countries such as Sweden, Norway and France, as well as by the JRC (Joint Research Center of the European Commission). Handbook 3.2, the most recent version was published after several up-dates in 2014.[18]

HBEFA provides emission factors for the most common vehicle types (passenger cars, light-duty vehicles, heavy-duty vehicles, urban buses, coaches and motor cycles), differentiated by emission concepts (Euro 0 to Euro VI) and by different traffic situations. HBEFA provides emission factors for all regulated and some important non-regulated pollutants including fuel consumption and CO_2.[19]

Current handbook version 3.2

HBEFA version 3.2 provides by now comprehensive measurement data for EURO 5 LDVs (light-duty vehicles) and some initial data on EURO 6 PCs (passenger cars). The required measurements

[17] KELLER, M. et al. (2004), p.19

[18] INFRAS (2014)

[19] HBEFA Introduction – General: http://www.hbefa.net/e/index.html

were carried out on a roller test bench according to the new ERMES driving cycle apart from the established CADC test. Additional emission tests of EURO V vehicles were collected for HDVs (heavy-duty vehicles). These tests included three vehicles with EURO V EGR technology. Furthermore, emission tests of five EURO VI vehicles were carried out on HDV roller test benches for both engine dyno tests and in-use tests.

Parameterisation of fuel consumption and CO_2 emissions based on CO_2 monitoring data of new registrations of passenger cars in NEMO

As described above under the item Model input data, the emission calculation model NEMO uses specific emission factors of different vehicles from HBEFA. NEMO also takes into account and annually up-dates the specific data regarding fuel consumption determined by type approvals (NEDC), which is annually collected by Statistics Austria and are part of the CO_2 monitoring of the fleet of newly registered passenger cars. Since real-world emissions are higher than NEDC consumption data (the reasons were described in detail in chapter 2.3), NEMO corrects the consumption values and CO_2 emissions in gram per km coming from CO_2 monitoring of the Austrian fleet of newly registered passenger cars and the Handbook Emission Factors Road Transport.

3 CALCULATION OF SCENARIOS AND GREENHOUSE GASES IN AUSTRIA

3.1 Austria-specific Analysis of Manufacturers

There are many publications on a European level which analyse and quantify the divergence between CO_2 emissions according to type approvals and real-world emissions (cf. chapter 2.3.1). The present study calculated this divergence especially for the Austrian fleet.

As a first step, based on a special analysis of data provided by Statistics Austria, the 30 models with the most new registrations in Austria between 2000 and 2013 were determined according to their engine features. Then average real-world fuel consumption in litres per 100 kilometres was calculated for every model by the means of the real-world consumption database www.spritmonitor.de This real-world fuel consumption values was then converted into an emission factor for CO_2 in grams per kilometre. Spritmonitor.de is publicly accessible and data is provided by private users and company fleets, although the majority comes from private users. It needs to be noted that for certain models the database holds only a few data sets (in extreme cases only one single value); for common models, however, several hundred data sets per construction year are available. Due to a weighted consideration of the data, however, underrepresented data sets only have a very low share of the calculated annual mean, thus reducing the impact of such single entries to a minimum. Depending on the year of analysis, the database comprises a total of between 800 and 1300 consumption data sets for the respective top 30 models.

The CO_2 emissions according to type approvals which were stated by the manufacturers were taken from different databases (http://autokatalog.autoscout24.de/, http://co2db.de/, Wikipedia)[20] and the product catalogues of the manufacturers. This data was compared with real-world data in order to calculate a divergence for every model. Finally a divergence value for every year was calculated for petrol-powered, diesel-powered and for all vehicles, weighted according to the number of registrations. Depending on the data source there are significant divergences in the data. A reason could be different specifications or drive variants. However, it is also striking that depending on the respective database the conversion from consumption to CO_2 emissions is also not done correctly or not using uniform factors, although CO_2 emissions are directly proportional to fuel consumption.

If different consumption or emission information for individual models was found, the higher CO_2 emission value was used for the analysis, i.e. a conservative approach was chosen for calculating divergences between test results and real-world results. The following table shows the results for the registration year 2013 as an example.

[20] The database autoverbrauch.at was also analysed. However, it only holds consumption and CO_2 values for current models, which makes an analysis back to the year 2000 impossible

Rank	Designation in registration statistics	Power in [kW]	CO_2 acc. to (NEDC) [g/km]	ØCO_2 in real-world driving [g/km]	Divergence from NEDC
1	VW POLO 6R 1.2 60	44	128	153.27	19.74%
2	Hyundai I 20 1.25	63	119	153.27	28.80%
3	VW TIGUAN 2.0TDI	81	139	170.58	22.72%
4	VW GOLF VII 1.6TDI	77	99	141.06	42.48%
5	VW SHARAN 7N 2.0TD	103	143	187.99	31.46%
6	Nissan QASHQAI 1.6DCI	96	129	172.96	34.08%
7	VW TIGUAN 2.0TDI ALL-WHEEL	103	157	186.40	18.73%
8	VW GOLF VII 1.2TSI	63	113	141.55	25.27%
9	VW TOURAN 1.6TD	77	121	162.41	34.22%
10	Fiat 500 1.2 8V 69	51	119	148.12	24.47%
11	VW GOLF VII 1.6TDI	66	98	145.01	47.97%
12	Seat ALHAMBRA 7N 2.0TDI	103	167	189.57	13.51%
13	Renault MEGANE SCENIC III 1.5DCI	81	130	162.41	24.93%
14	VW 7H BUS DS	103	199	234.92	18.05%
15	Audi Q3 2.0TDI QUATTRO	103	149	175.07	17.49%
16	Hyundai I 30 GD 1.4	73	135	172.72	27.94%
17	Ford FIESTA JA8 1.25 44KW	44	127	156.08	22.90%
18	Ford GALAXY 2.0TD/103KW	103	152	181.66	19.51%
19	Skoda OCTAVIA 1Z 1.6TDI ESTATE	77	119	141.32	18.76%
20	BMW X3 XDRIVE20D F25	135	149	197.48	32.54%
21	Seat IBIZA 6J 1.2	51	139	162.88	17.18%
22	Skoda YETI 5L 2.0TDI 110	81	140	156.35	11.68%
23	Hyundai IX 35 2.0CRDI	100	147	204.60	39.18%
24	Skoda OCTAVIA 5E 1.6TDI ESTATE	77	99	146.59	48.07%
25	BMW X1 XDRIVE18D E84 MUE	105	150	180.60	20.40%
26	Mazda 2 1.3I 55KW	55	125	159.83	27.87%
27	Ford KUGA 4WD 2.0TD 103KW	103	159	182.71	14.91%
28	Audi A3 8V 1.6TDI SPORTBACK	77	102	146.59	43.72%
29	Dacia SANDERO 0.9	66	120	164.76	37.30%
30	Hyundai IX 20 1.4	66	130	191.47	47.29%
	Divergence for petrol-powered vehicles weighted acc. to registration				26.09%
	Divergence for diesel-powered vehicles weighted acc. to registration				27.84%
	Divergence for sum total of vehicles weighted acc. to registration				**27.18%**

Table 4: New registrations and divergences in CO_2 emissions between real-world driving and type approval in 2013

The analysis of divergences was carried out for the years between 2000 and 2013. Within this period of time the gap between CO_2 emissions from real-world driving and type approval results has increased fourfold. In 2000 the average divergence was about 7%. However, in 2013 it was already about 27% (cf. Fig. 12). A further increase is already expected for the years 2014 and 2015 according to international studies.

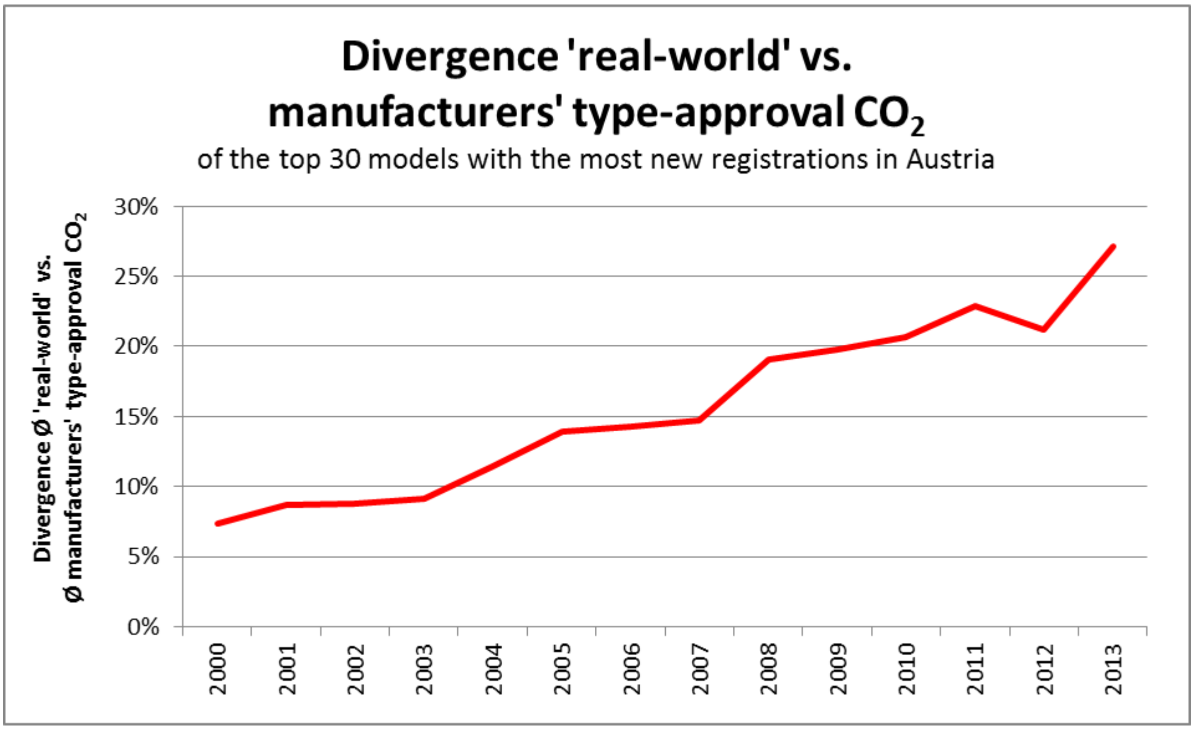

Figure 12: Divergences between CO_2 emissions acc. to manufacturers' type-approval and real-world driving of the 30 models with the most new registrations per year in Austria

The analysis of divergences according to the manufacturers (Table 5) shows that between 2000 and 2013 a total of 21 different car manufacturers were represented with up to 4 models per year in the list of the top 30 models of newly registered vehicles. Volkswagen is an exception, since it always has 7 to 12 models ranked in the list and as a group including the makes Audi, Seat and Skoda it even has 11 to 18 models represented.

Many manufacturers are represented with only one model per year. The results determined by this study are therefore not applicable to the entire product range of a make. However, the respective models are the best-selling models of the respective car manufacturers in Austria.

Figure 13 below shows the consumption figures per model stated in the database of spritmonitor.de for the 30 models with the most new registrations in Austria in 2013. In addition to the average fuel consumption given in the database for the respective model (according to the type of engine and fuel), minimum and maximum consumption are shown in the table in order to give an overview of the scattering of fuel consumption data. As the table shows there are no extreme upward or downward divergences of the models in the database, the data for real-world driving scatter to a normal extent. Additionally the average values show a tendency towards minimum consumption.

However, the figure clearly shows that data availability regarding single models needs to be seen in a critical light. For one vehicle, a Mazda 2 1.3l, only one reference vehicle with exactly the same engine and year is available in the database. The figure, therefore, does not specify any minimum/maximum scattering. For calculating the average divergence for the entire fleet this is of minor significance, though, since the values are included in the consumption factor based on their weighting according to the number of data sets in the database.

Additionally such entries were, however, further scrutinised regarding their plausibility. The respective model is listed with a consumption of 6.8 litres for 2013. An analysis of the same model with the same motorisation over the entire time period in which it was available (2008 – 2014) shows an average fuel consumption of all stated models of 6.4 litres (minimum value 5.1 litres, maximum value 8.5 litres). The single value in 2013 hence has a divergence of +6% over all entries of this model and over the entire period in which it was constructed, which is a value that hardly impacts the accuracy of the overall information and lies within the range of consumption divergences in real-world driving.

The analysis, however, also says something about the solidity of the data. Volkswagen's 1.6 litre TDI engine is listed with five models in the top 30: 2 x Golf (66 and 77kW), the VW Touran, the Skoda Octavia and the Audi A3. Regarding weight and size, the Golf, Skoda and Audi models compare well, with their real-world fuel consumption data in the database showing practically the same value for all 4 vehicles in the database (5.3 – 5.5 litres). The Touran consumption data is a little bit higher with 6.2 litres due to more vehicle weight and a higher chassis setup. In general, all the calculated average values of the respective vehicles lie within a very plausible range.

Chrysler's Voyager, for instance, made it into the top 30 list in 2000, and according to the real-world consumption database www.spritmonitor.de, used even about 7% less fuel and emitted less CO_2 than stated by the manufacturer. The Sports Utility Vehicle (for short: SUV) KIA Sorrento 2.5TD, however, was ranked 30 of the most registered new cars in 2006 and with approx. 32% increased consumption it was even at that time above the fleet average of 14.3% by a factor of 2. In the same year and in the following year an increased consumption of about 25% was calculated for the off-road vehicle Suzuki Grand Vitara 1.9DS. Another SUV, the Nissan Qashqai 1.6dCi showed similar results, with an increased consumption of about 34% in 2012 and 2013. Also in 2013 the Dacia Sandero 0.9 (66kW) showed an increased consumption of approx. 37%.

The analysis of the aforementioned makes is not representative for the entire product range of a manufacturer with regards to a single year. However, the sum total of all manufacturers results in a valid "per year" data basis regarding divergences between test cycle consumption and real-world consumption, as well as CO_2 emissions for the majority of newly registered cars per year in Austria.

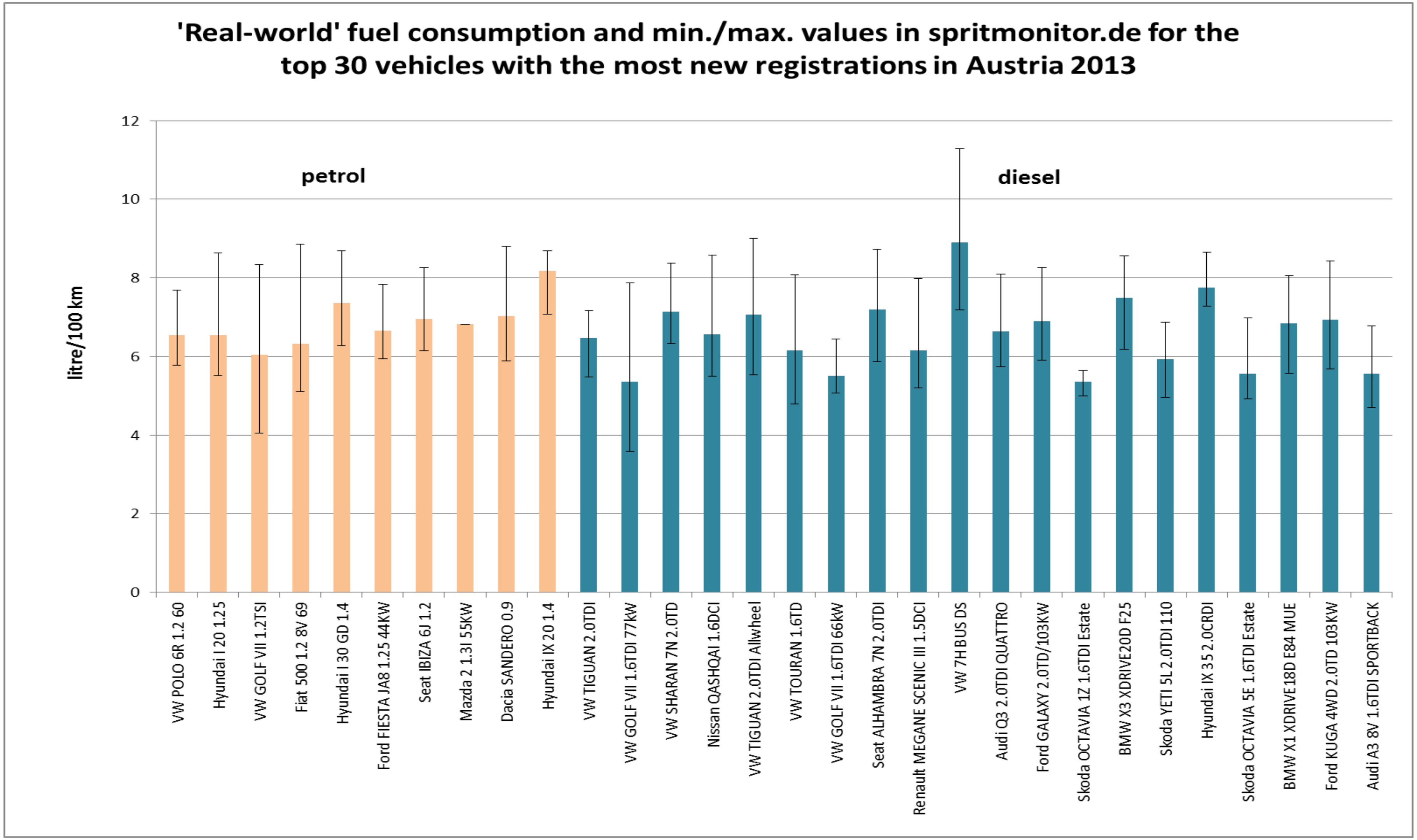

Figure 13: Real-world consumption data and fluctuation range of data from the database spritmonitor.de for the top 30 models, broken down by petrol and diesel, in 2013 in Austria

Make	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Audi	12% (1)	14% (1)	12% (3)	8% (2)	15% (2)	12% (2)	15% (2)	15% (2)	31% (3)	18% (2)	22% (1)	32% (1)	29% (2)	28% (2)
BMW	13% (1)	-	-	-	-	16% (1)	-	-	19% (1)	-	-	27% (2)	27% (1)	27% (2)
Chrysler	-7% (1)	-	-	-	-	-	-	-	-	-	-	-	-	-
Citroen	-	-	14% (1)	10% (1)	-	-	11% (1)	22% (1)	25% (1)	20% (1)	19% (1)	19% (1)	17% (1)	-
Dacia	-	-	-	-	-	-	-	-	-	20.13%	10% (1)	-	-	37% (1)
Fiat	8% (2)	10% (1)	13% (1)	12% (2)	9% (1)	14% (2)	-	31% (1)	27% (2)	21% (4)	15% (3)	22% (3)	23% (3)	24% (1)
Ford	11% (2)	14% (2)	9% (2)	9% (3)	13% (3)	14% (1)	-	17% (1)	28% (1)	28% (3)	24% (3)	26% (3)	22% (3)	20% (3)
Hyundai	-	-	-	-	-	21% (1)	15% (2)	22% (1)	17% (1)	21% (2)	27% (4)	25% (2)	26% (3)	33% (4)
Kia	-	-	-	-	-	-	32% (1)	-	-	-	-	-	-	-
Mazda	0% (2)	-2% (1)	-3% (1)	3% (2)	9% (2)	8% (2)	15% (2)	11% (2)	21% (1)	20% (1)	23% (2)	12% (1)	14% (1)	28% (1)
Mercedes	-	-2% (1)	3% (2)	-	-	-	-	20% (1)	-	-	-	-	-	-
Mitsubishi	-	-	-	-	-	-	-	3% (1)	11% (1)	-	-	-	14% (1)	-
Nissan	-	-	-	-	-	-	-	-	-	-	-	-	34% (1)	34% (1)
Opel	2% (4)	9% (3)	9% (2)	9% (2)	11% (3)	16% (4)	10% (3)	15% (3)	15% (3)	16% (3)	15% (3)	19% (3)	-	-
Peugeot	-4% (2)	13% (2)	-	29% (1)	16% (1)	14% (1)	-	-	-	22% (1)	-	-	-	-
Renault	16% (1)	8% (1)	7% (2)	3% (2)	12% (2)	-	14% (1)	10% (1)	-	-	26% (1)	27% (1)	21% (1)	25% (1)
Seat	-	14% (1)	14% (1)	17% (1)	18% (1)	9% (1)	21% (1)	-	23% (2)	16% (3)	19% (1)	18% (2)	13% (2)	15% (2)
Skoda	2% (4)	-1% (4)	13% (3)	5% (3)	2% (3)	11% (3)	12% (2)	12% (1)	15% (2)	15% (2)	22% (1)	18% (1)	17% (1)	25% (3)
Suzuki	-	-	-	-	-	-	25% (1)	25% (1)	19% (1)	-	-	-	-	-
Toyota	5% (2)	6% (2)	5% (2)	-6% (1)	14% (1)	10% (2)	4% (2)	11% (2)	-	-	12% (1)	-	-	-
Volkswagen	12% (8)	11% (11)	11% (10)	11% (10)	13% (11)	15% (10)	15% (12)	14% (12)	16% (11)	20% (7)	21% (8)	24% (10)	21% (10)	28% (9)
Weighted divergence petrol	9% (7)	9% (4)	11% (4)	14% (3)	11% (4)	13% (11)	13% (9)	14% (10)	17% (11)	19% (22)	19% (18)	22% (14)	19% (14)	26% (10)
Weighted divergence diesel	7% (23)	9% (26)	8% (26)	9% (27)	12% (26)	14% (19)	15% (21)	15% (20)	20% (19)	20% (8)	23% (12)	23% (16)	23% (16)	28% (20)
Weighted divergence sum total	**7% (30)**	**9% (30)**	**9% (30)**	**9% (30)**	**11% (30)**	**14% (30)**	**14% (30)**	**15% (30)**	**19% (30)**	**20% (30)**	**21% (30)**	**23% (30)**	**21% (30)**	**27% (30)**
Legend	<5%		5% to <10%		10% to <15%		15% to <20%		20% to <25%		25% to <30%		≥30%	

Table 5: Divergences of CO_2 emissions between real-world driving and type approval, and number of considered models (in brackets) per manufacturer and year

Five manufacturers - Audi, Ford, Opel, Skoda and Volkswagen – were represented with more than one model in the top 30 list of newly registered cars in at least 10 of the 14 years between 2000 and 2013. If selective fluctuations due to the low number of reference vehicles are taken into account then all five makes, should the tendency continue, show a trend of increasing divergence between real-world CO_2 emissions and type approval results. Figure 14 shows a comparison of divergences of the entire analysed fleet with trend lines of the five aforementioned makes.

The biggest gap in both the manufacturer's specifications and the weighted average of the divergence can be ascertained in Audi's high-performance models. Ford's models Fiesta, Galaxy and Kuga have also helped to increase its weighted real-world fuel consumption to above average in recent years. Since 2008, however, the divergence between real-world consumption and type approval results has decreased, which is reflected in a flatter trend line.

Volkswagen is close to the average value of the analysed fleet. Its representation in the statistics of newly registered cars lies above average with its models Golf, Polo, Sharan, Tiguan, Touran and Transporter in different types of motorisation. Skoda, part of the Volkswagen group, shows less divergence in its models Alhambra, Fabia, Octavia and Yeti, which are below the weighted average divergence. However, Skoda's trend line shows the biggest increase, and the greatest divergence for 2013 – approx. 48% - was calculated for the model Skoda Octavia 5E 1.6TDI estate (77kW).

Also Opels divergence always was below the weighted average in the period considered. Opel is represented in the statistics of newly registered cars especially with small (Corsa, Meriva) and middle-class models (Astra), as well as with its family van Zafira. Although no Opel was ranked in the top 30 list of newly registered cars in Austria in 2012 and 2013, the development in the years before showed a decrease in the divergence, which is also reflected in the respective trend line.

Hyundai has only been in the top 30 list of newly registered cars in Austria since 2005. However, since then it has been strongly represented with up to four models, amongst them the I10, I20, I30 IX20, IX35 and Tucson. The aforementioned models are vehicles of different categories, and the divergence between real-world consumption and specifications by the manufacturer is consistently above the weighted average of the analysed fleet. In 2013, for instance, Hyundai was in the list with four models with a divergence of between about 28% and 47%.

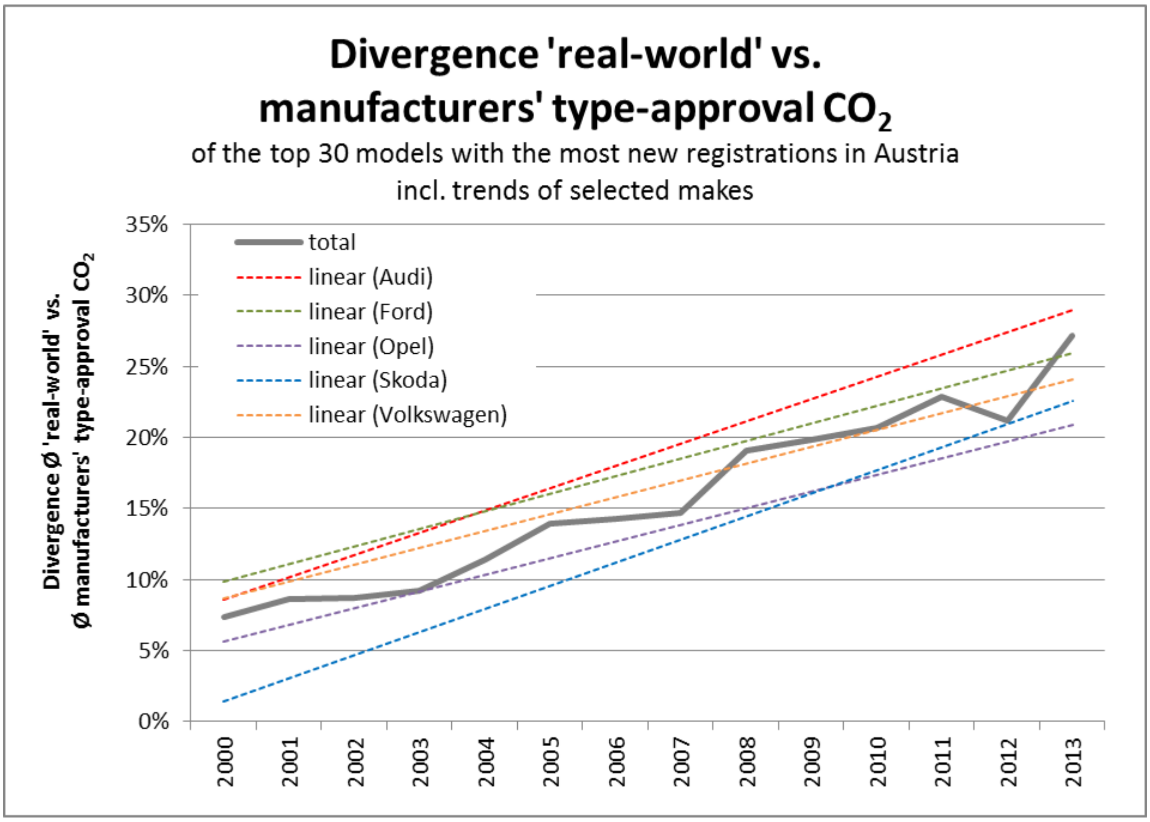

Figure 14: Divergences between CO_2 emissions acc. to type approval and real-world driving incl. trend lines of certain makes

The results of considering the divergence between type approval and real-world driving (Figure 12) on the average CO_2 emissions of newly registered vehicles in Austria according to type approvals are shown in Figure 15. Although there is a reduction in CO_2 emissions in both type approvals and real-world driving in the years between 2008 and 2012, the emissions from real-world driving do not decrease to the same extent as in the type approvals, resulting in an ever increasing gap between the two curves. The data analysis within the framework of this project even showed an increase in CO_2 emissions from real-world driving for 2013 compared to the year before. Especially striking, however, is also the fact that real-world consumption of newly registered vehicles in Austria increased between 2000 and 2008 and only started to sink following the introduction of mandatory targets. The improvement of engine technologies in this period therefore compensated the trend towards stronger and heavier vehicles.

The calculation shows a real-world average emission factor of about 167g CO_2/km instead of the reported 132g CO_2/km in 2013. The newly registered vehicle fleet of 2013 (Federal Ministry of Agriculture, Forestry, Environment and Water Management, BMLFUW 2014) comprised 57% diesel and 43% petrol-powered cars and the average increased consumption in comparison to manufacturers' specifications can be calculated at 1.42 l/100km. This results in increased expenses for drivers of € 0.0197 per kilometre for operating a petrol-powered vehicle and € 0.0192 per kilometre for a diesel-powered vehicle[21]. In 2013 the increased expenses thus totalled € 296 for petrol-powered cars and € 288 for diesel-powered vehicles assuming an average annual mileage of 15,000 kilometres.

[21] Average fuel price 2013: Petrol € 1.39 per litre and diesel € 1.35 per litre. Source: http://autorevue.at/autowelt/spritpreise-osterreich-2013

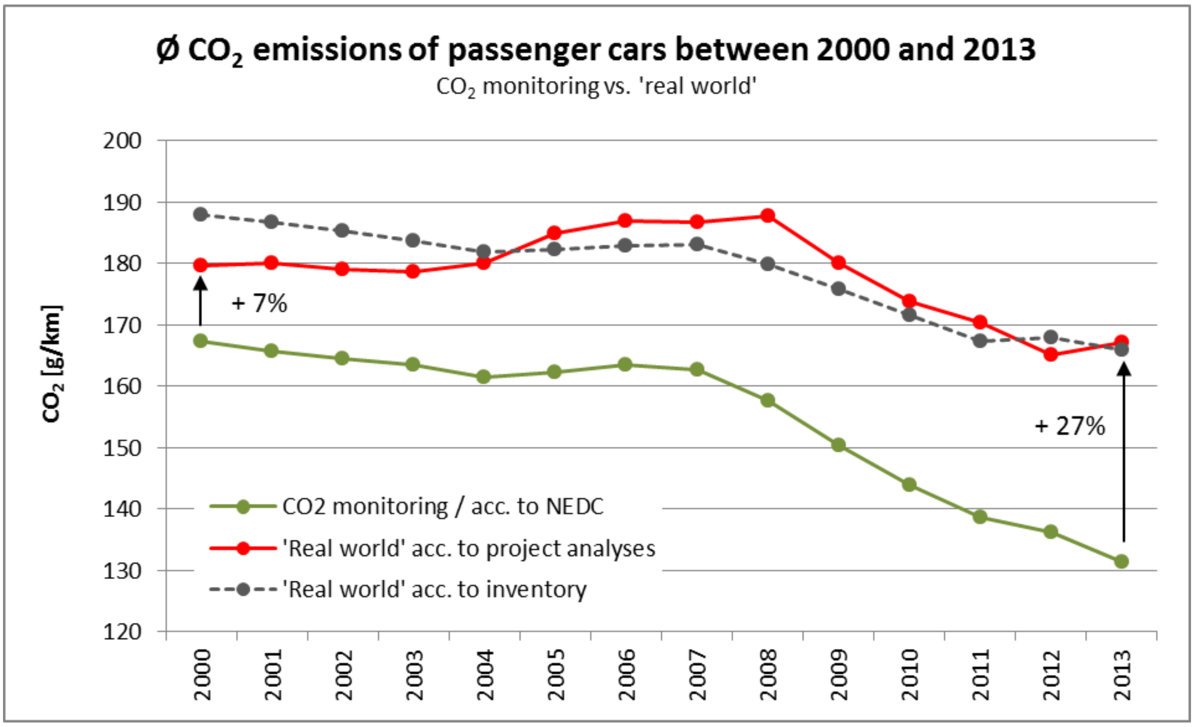

Figure 15: Average CO_2 emissions of passenger cars between 2000 and 2013

Projections of the development of CO_2 emissions according to type approvals by the Graz University of Technology shows that the mandatory limit of the European Union of 130g CO_2/km in 2015 will be met and exceeded. The limit of 95g CO_2/km for 2021 is also expected to be met. It needs to be mentioned that both the mandatory limits and the continuation of emission factors for CO_2 emissions (and therefore also the continuation of divergences) are based on the assumption that the NEDC will continue to be applied unchanged and that, due to vehicle adaptions by the manufacturers, the new WLTP cycle will not result in significant changes in divergences between type approval results and real-world consumption. Therefore, it is presumed that there will be a significant increase in the divergences between real-world emissions and type approval results of about 48% in 2020 and about 72% in 2030 (cf. Fig. 16).

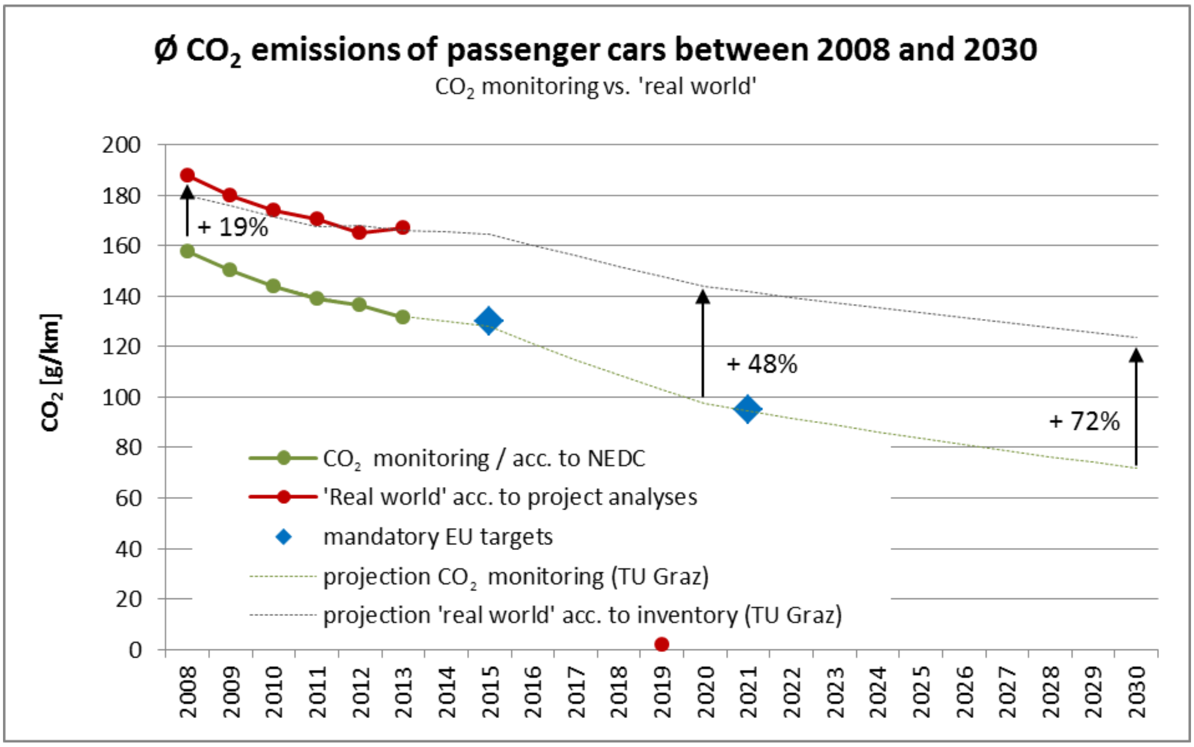

Figure 16: Average CO_2 emissions of passenger cars between 2008 and 2013 with extrapolation until 2030

3.2 Scenarios for the Development of GHG Emissions in Austria

As described above, air pollution and greenhouse gas emissions of traffic are determined each year for the Austrian Air Emission Inventory (*Österr. Luftschadstoffinventur*) using the emission model NEMO (Network Emission Model). They are then reported to the European Commission. The necessary correction factors for depicting real-world driving are developed and permanently up-dated based on available international studies, as well as many test bench measurings carried out at Graz University of Technology. The CO_2 emissions from traffic calculated with the aforementioned methods for the Air Emission Inventory totalled about 150.5 million tonnes between 2000 and 2013.

The present project used those factors for calculating overall emissions which were determined especially for the Austrian fleet beforehand (cf. chapter 3.1 Austria-specific Analysis of Manufacturers), in order to again calculate overall CO_2 emissions by the means of the NEMO model. The result of about 150.0 million tonnes CO_2 between 2000 and 2013 deviates insignificantly from the inventory result. This confirms the solidity of the results of the analysis.

Assuming that the real emission factors matched the NEDC type approval emissions, the overall CO_2 emissions would total about 133.3 million tonnes in the aforementioned period. This is a difference of approx. 11.13% to 11.43% (see Figure 17).

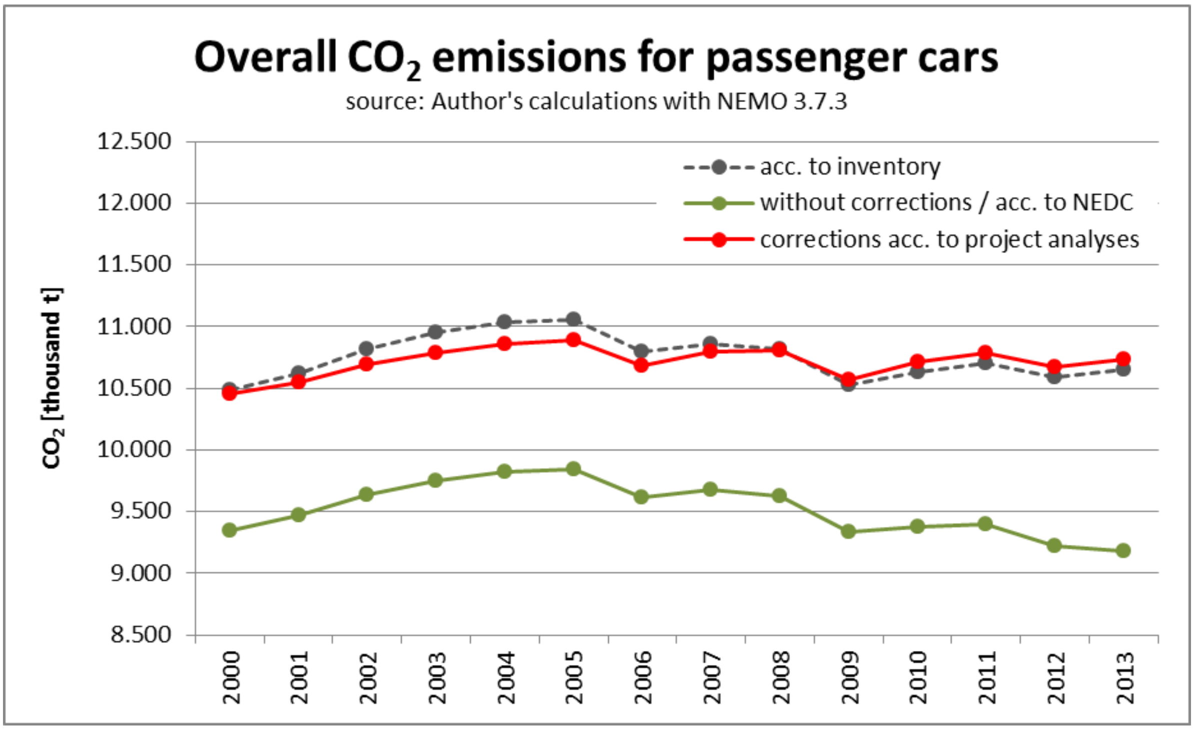

Figure 17: Overall CO_2 emissions for passenger cars between 2000 and 2013

The Kyoto targets for the period between 2008 and 2012 were exceeded by about 69 m tonnes of CO_2 equivalents across all sectors in Austria. The transport sector was a significant contributor and of all the sectors, exceeded the sectoral targets of the climate strategy 2007 the most. Greenhouse gas emissions caused by the transport sector exceeded the sectoral target of 18.9 m tonnes of CO_2 equivalents set under the climate strategy by about 2.8 m tonnes (Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, BMLFUW 2007).

The difference between the emissions according to the Inventory (Figure 17, red curve) reported for the settlement of the Kyoto period, and the theoretical emission level, assuming that real-world emissions had matched NEDC emissions (green curve) is about 6.3 m tonnes of CO_2 for the Kyoto period between 2008 and 2012. The monetary value of the purchased emission certificates needed totals approx. € 39 m[22].

Year	Overall CO_2 emissions for passenger cars in thousand tonnes		
	Acc. to Inventory	Without correction / matches NEDC	Difference
2008	10,821	9,629	1,192
2009	10,525	9,335	1,190
2010	10,631	9,377	1,254
2011	10,708	9,394	1,314
2012	10,589	9,217	1,372
Sum	**53,274**	**46,952**	**6,322**

Table 6: Overall CO_2 emissions for passenger cars between 2008 and 2012

22 The average purchase price is € 6.20 per emission certificate (one certificate = 1 tonne) (Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, BMLFUW 2015)

4 IMPACT ON NITROGEN OXIDE EMISSIONS

4.1 Nitrogen Oxides and their Impact on Human Health and the Environment

Nitrogen oxides (NO_x) comprise nitrogen monoxide (NO) and nitrogen dioxide (NO_2). Due to the fact that concentration levels of NO_2, as they could be found in the ambient air, impair lung function, NO_2 is a much bigger threat to human health than NO (WHO 2013a, 2013b).

As ozone precursors, nitrogen oxides (NO_x) play a significant role and contribute to acidification and eutrophication (overfertilisation) of soil and water. Particulate ammonium nitrate, which can develop in the atmosphere from gaseous nitrogen oxides and ammonia, contributes as precursor for the development of particulate nitrate significantly to large-scale PM_{10} pollution, especially in the cold season of the year. NO_x predominantly develops as an unwanted side-product of the combustion of fuels at high temperatures (ENVIRONMENT AGENCY AUSTRIA, *UMWELTBUNDESAMT* 2015d).

In order to reduce this impact and avoid it on a long-term basis the European Union - and therefore Austria – have developed a comprehensive legislative framework on emissions, product regulations and limits regarding the pollution of ambient air. The most important regulations are:

- Source-related stipulations regarding emissions (e.g. regulations for passenger cars, power plants and industry)
- Product-related stipulations (e.g. for fuels and devices)
- The EU Ambient Air Quality Directive in order to protect human health and the environment implemented by the Austrian Air Quality Protection Act (*Immissionsschutzgesetz-Luft, IG-L*)
- National maximum emission limits in order to meet certain environmental targets Europe-wide and in a cost effective manner (the NEC Directive – National Emission Ceilings –, implemented by the Austrian Air Emission Ceilings Act (*Emissionshöchstmengengesetz-Luft*))

These requirements are exceeded regarding the limit of the annual mean level of NO_2 in ambient air, as well as the national emission ceilings for NO_x (ENVIRONMENT AGENCY AUSTRIA, *UMWELTBUNDESAMT* 2015c, 2015d).

4.2 Reasons and Trends

NO_x predominantly develops as an unwanted side-product of the combustion of fuels at high temperatures. The transport sector causes the most NO_x emissions in Austria. In 2013 it was even the greatest emitter of NO_x, followed by the sectors industry and small-scale commercial.

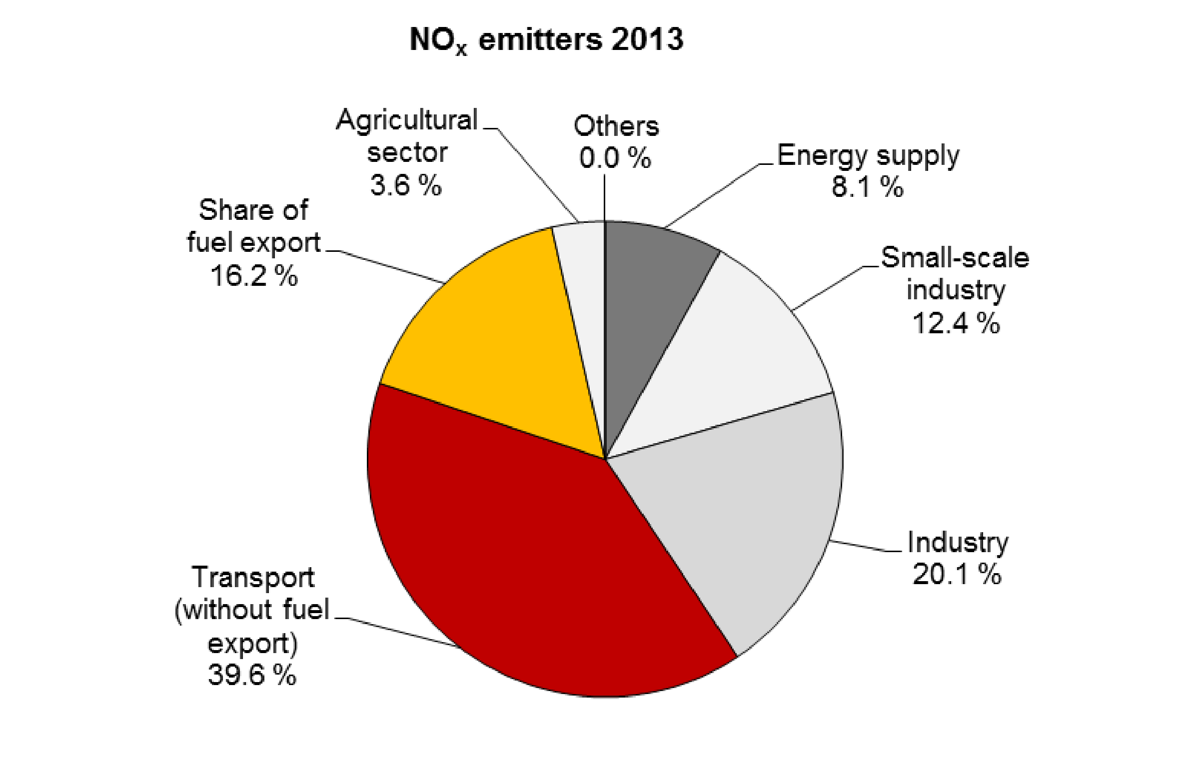

Figure 18: Share of each sector in causing NO_x emissions in Austria

As described in chapter 4.1, nitrogen oxides NO_x comprise NO and NO_2. In most sources NO_x in exhaust gas is made up of 90% or more NO. Diesel vehicles are an exception, their share of NO_2 in exhaust gas is very much higher due to higher engine-out emissions and the built-in exhaust after-treatment systems (see chapter 4.4). Irrespective of the share of NO in NO_x, NO reacts slowly with ozone to form NO_2; thus the share of NO in NO_x is very low outside of cities and away from roads (although only at a generally low pollution level).

Between 1990 and 2013 nitrogen oxide emissions were reduced in Austria by a total of 25% to approx. 162,300 tonnes, whereby in 2013, 1.4% less NO_x was emitted than in the year before. In 2013 emissions, minus emissions from fuel export (fuel exported in the tank) totalled approx. 136,000 tonnes of NO_x (- 3.6% compared to 2012).

The transport sector is the main reason for the reduction in NO_x emissions since 2005, due to the progress in exhaust after-treatment, especially in diesel vehicles.

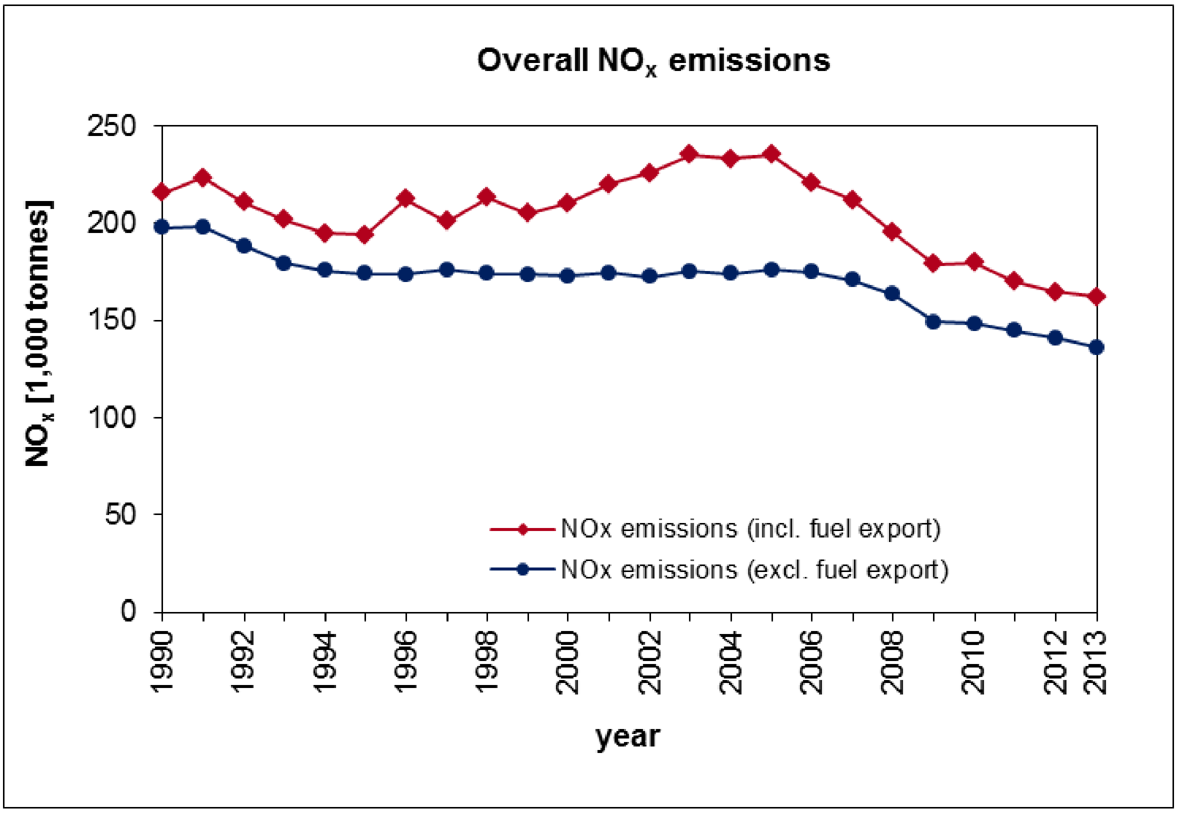

Figure 19: NO_x emission trends (incl. and excl. NO_x from fuel export)

For monitoring the concentration of nitrogen oxides in the ambient air, Austria operated 143 NO_2 and NO_x measurement points pursuant to the Austrian Air Quality Protection Act (*Immissionsschutzgesetz-Luft, IG-L*) in 2014. 16 of these IG-L measurement points were additionally operated for monitoring the limits for the protection of eco-systems and vegetation. The limits for NO_2 set in the IG-L (half-hour average value of 200 µg/m³, annual mean value of 30 µg/m³) were exceeded at 30 measurement points in 2014 (in all Federal Provinces except Burgenland). The limit for the annual mean value (30 µg/m³) was exceeded at 29 measurement points, while the limit for the half-hour average value of 200 µg/m³ was exceeded at five measurement points.

The sum total of limit and margin of tolerance (5 µg/m³) for the annual mean value – i.e. an annual mean value of 35 µg/m³ was exceeded at 18 measurement points. The limit of the annual mean value set in the Ambient Air Quality Directive (40 µg/m³) was exceeded at 11 measurement points in 2014.

Limits pursuant to IG-L are more often exceeded in the cities of Vienna, Linz, Salzburg, Graz and Innsbruck, in urban areas close to traffic, for example in Klagenfurt, St. Pölten, Hallein, Lienz, Lustenau and Feldkirch, as well as in areas alongside motorways.

In general, it can be presumed that the limits are also exceeded on other motorways and in other towns situated in heavy traffic areas, where no measurement points are installed.

The trend of NO_2 and NO_x concentrations is illustrated as the average value of different types of measurement points in Figure 20. The development follows more or less the Austrian-wide development of NO_x emissions; with NO_2 super-imposed by the increased primary NO_2 emissions of diesel vehicles. The pollution for areas close to traffic increased until about 2006, after which it has decreased. In urban areas (i.e. in residential areas away from roads with heavy traffic) the pollution level largely remained stable until 2011. Only afterwards it decreased slightly.

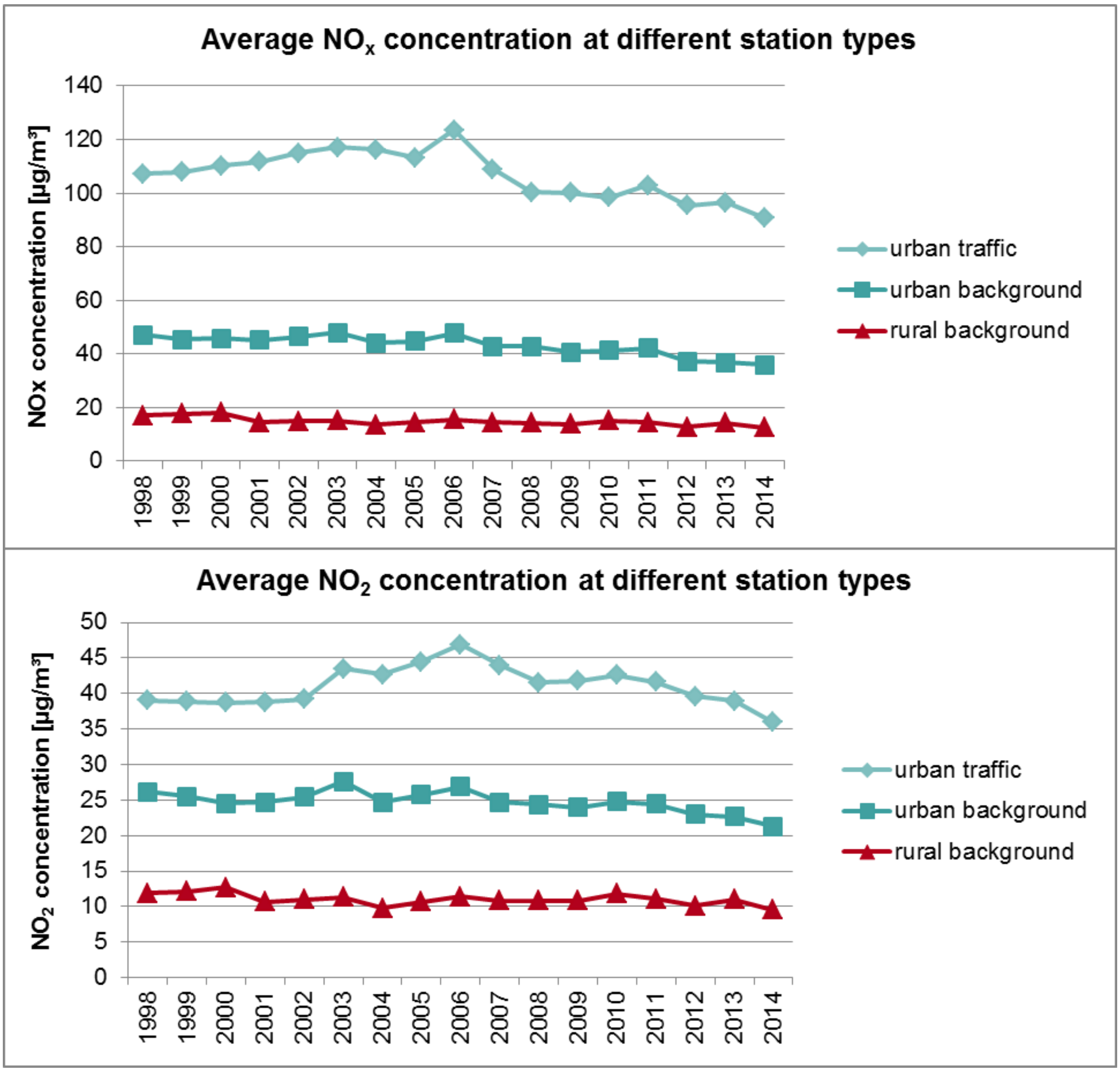

Figure 20: Average value of NO_x and NO_2 concentration measured at different station types, 1998–2014 (Source: ENVIRONMENT AGENCY AUSTRIA, *UMWELTBUNDESAMT* 2015d, Provincial Governments, Environment Agency Austria (*Umweltbundesamt*))

4.3 Relation between Emissions and Immissions

NO_2 is partially directly emitted. For the most part, however, it develops in the atmosphere by conversion from nitrogen monoxide (NO), which is primarily emitted during combustion processes. At places away from emitters a great proportion of the nitrogen oxides (NO_x = NO + NO_2) is made up of NO_2, since NO is unstable and is oxidised to a large extent (about 90%) in the atmosphere, depending on the concentration of ozone, to form NO_2. However, the overall NO_2 concentration is low in ambient air at locations away from emitters (see Figure 18.)

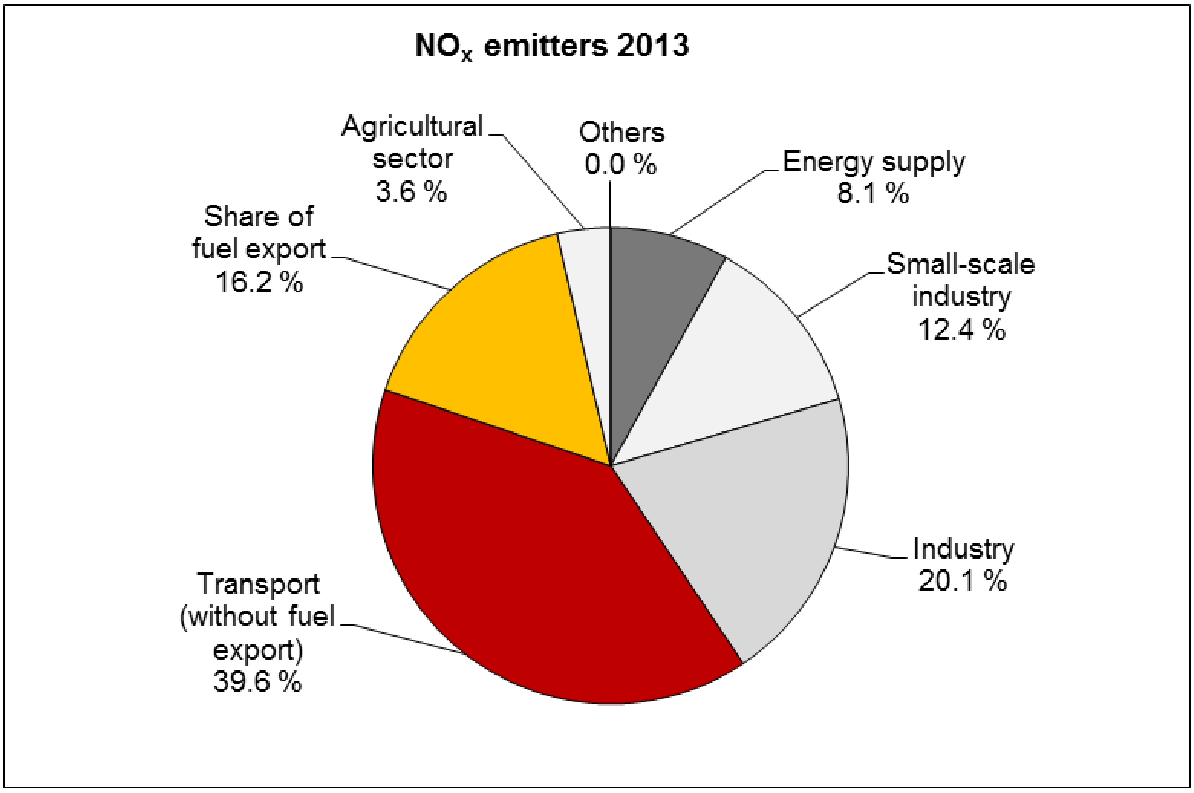

Figure 18: Share of each sector in causing NOx emissions in Austria

At measurement points close to traffic, however, only about 30 – 40% of all nitrogen oxides are made up of NO_2. Since the concentration of nitrogen oxides is in general very high at measurement points close to traffic due to close proximity to the emission sources, it is these points that most often register NO_2 values that exceed the limits.

Regarding the considerations on NO_x emissions and on the sectors which are causing them in chapter 4.2, it needs to be noted that they are given as a sum total, i.e. as the Austrian mean value. The transport sector as an emitter of NO_x emissions, however, plays a much more important role regarding local pollution levels, i.e. in cities and alongside roads with heavier traffic, while emissions from other sources (especially emissions from high-rise chimneys) become less important. Model calculations available for the cities of Vienna and Graz show NO_x shares from road traffic of 60 - 70%, locally up to 90% (KURZ et al. 2014; OFFICE OF THE STYRIAN PROVINCIAL GOVERNMENT 2013 (*AMT DER STEIERMÄRKISCHEN LANDESREGIERUNG 2013*); see also Figure 21 and Figure 22). Likewise, pollution close to roads is dominated by primary NO_2 emissions from diesel vehicles (see chapter 4.4).

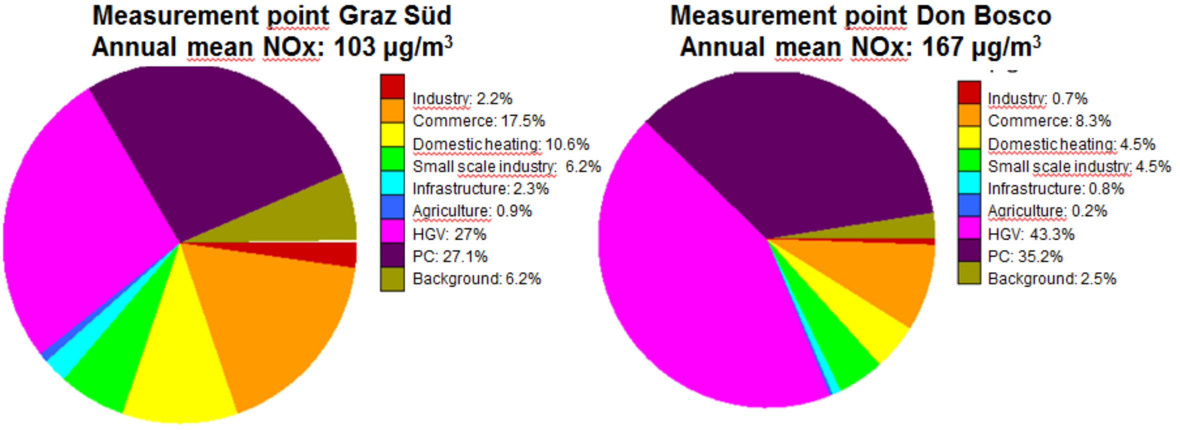

Figure 21: Modelled shares of different sources in the annual mean NO_x value at the measurement points Graz Süd and Don Bosco, reference year 2006 (source: OFFICE OF THE STYRIAN PROVINCIAL GOVERNMENT 2013 (*AMT DER STEIERMÄRKISCHEN LANDESREGIERUNG 2013*)

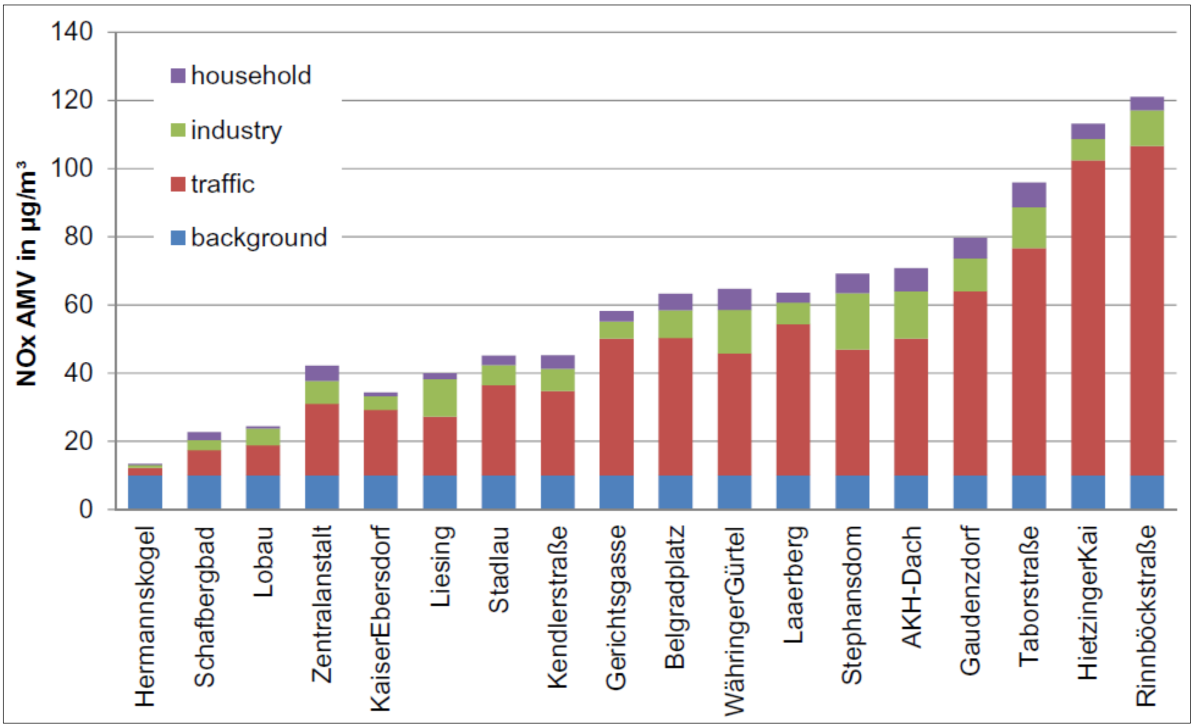

Figure 22: Modelled distribution of sources in the annual mean NO_x value at the measurement points in Vienna (source: KURZ et al. 2014)

4.4 Development of NO_2 Emissions in Vehicles

As discussed in chapter 3.1, NO_2 emissions have a special role amongst the nitrogen oxides. On the one hand they are a special threat to human health, and on the other immission limits are exceeded regarding the annual mean value of NO_2 at many measurement points close to roads.

Development

NO_2 develops primarily in the exhaust after-treatment system of diesel passenger cars. The exhaust system includes a ceramic or metallic diesel particulate filter for removing soot from the exhaust gas and keeping it within the filter. At the same time, this filter works as an oxidation catalyst, oxidising some of the pollutants with the excess oxygen from the lean air-fuel mixture diesel engines operate on. Simplified, carbon monoxide (CO) and hydrocarbons (HC) convert into carbon dioxide (CO_2) and water (H_2O), and nitrogen monoxide (NO) converts into nitrogen dioxide (NO_2). (This is contrary to petrol-powered engines, which work with a lack of oxygen. This mixture enables the 3-way catalyst to reduce nitrogen oxides; the released oxygen is sufficient to oxidise HC and CO).

The particulate filter (CRT System, continuous regenerating trap) which follows the oxidation catalyst needs the NO_2 which developed in the oxidation catalyst for regeneration, especially at low operating temperatures. A diesel vehicle with oxidation catalyst and particulate filter still emits NO and NO_2.

Reasons for high NO_2 concentrations at measurement points close to roads

- Strong increase in diesel vehicles/diesel mileage

The share of diesel passenger cars in relation to the sum total of vehicles in use has constantly increased since 1990. In 1990 it was 14%; in 2013 it had already reached 56%. Regarding commercial vehicles the share of diesel vehicles was 62% in 1990, increasing to 94% in 2013. About 60% of all kilometres driven by passenger cars in 2013 were driven by diesel vehicles. The increase in mileage by diesel vehicles between 1990 and 2013 was about 442%.

- Real-world NO_x emissions are much higher than type approval results

The figure below shows that the gap between real-world NO_x emissions (pursuant to HBEFA) and type approval results has not become smaller. The lowest divergence between real-world driving and type approval results is shown by EURO 2 vehicles; however, the level is quite high. Measurements of EURO 4 and EURO 5 vehicles show that real-world emission values exceed the results of the statutory test cycles by a factor of 2 (EURO 4) to a factor of 4 (EURO 5). This trend towards divergence continues in EURO 6, although there is not sufficient secured emission data available due to the low number of vehicles tested. This is the reason why at the moment only ranges for EURO 6 vehicles can be assumed (see Figure 23). The optimistic emission assumptions for EURO 6 vehicles are dark grey, while the pessimistic emission factors are light grey.

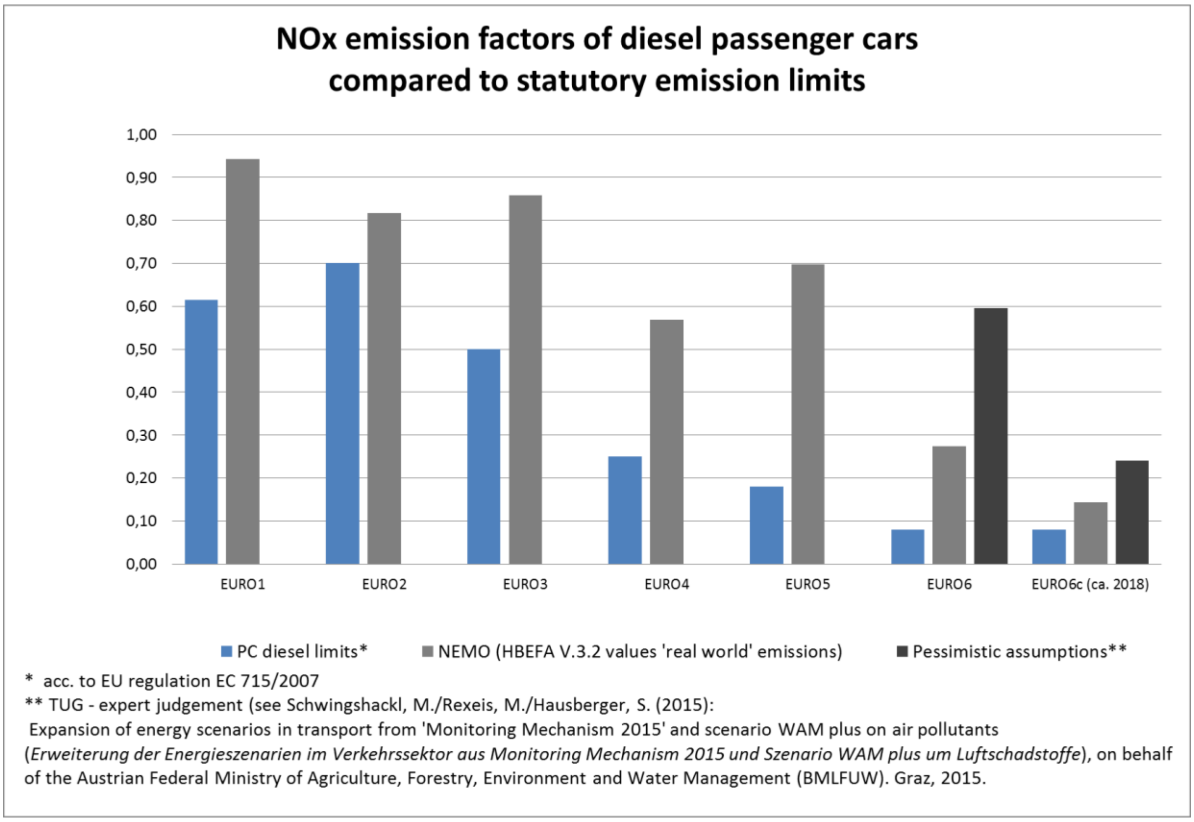

Figure 23: NO_x emission factors of diesel passenger cars–statutory limits vs real-world emissions

The European laws on NO_x emission limits for diesel passenger cars have thus not resulted in a clear decrease in specific real-world vehicle emissions in the last 20 years, although the limits themselves have seen a significant decrease.

4.5 Nitrogen Oxide After-Treatment Systems

Nitrogen oxide after-treatment systems are necessary in order to be able to meet Euro 6 exhaust standards. The state-of-the-art technology in this field is the SCR (Selective Catalytic Reduction) catalysts, which inject a 32.5% urea solution (e.g. AdBlue®) into the exhaust gas system, where it is subsequently hydrolysed into ammonia and CO_2. Ammonia reacts with the nitrogen oxides in the catalytic converter, which breaks down the nitrogen oxide into separate nitrogen and water elements. An alternative to the SCR catalyst is the adsorption catalyst. It regenerates about every 60 seconds with an enriched (lack of oxygen) fuel mixture, and thus shows disadvantages regarding CO_2 and fuel consumption. Regarding its potential to reduce NO_2, however, it is limited and can only be a temporary solution in the long run.

Modern, heavy-duty vehicle engines (Euro VI) have several exhaust after-treatment systems, exhaust gas recirculation to reduce NO_x in the engine, Diesel Oxidation Catalyst (DOC) for developing NO_2 and reducing HC and CO, DPF for filtering particles and SCR for reducing NO_x. Heavy-duty vehicles of emission standard Euro VI (already introduced for heavy-duty vehicles in 2013) show a low emission level even in real-world driving situations. This standard still needs to be met with passenger cars due to the delayed introduction of stricter testing procedures.

4.6 NEC Target & Reason for Failure

In 1979 the United Nations Economic Commission for Europe (UNECE) put into force the Geneva Convention on Long-range Transboundary Air Pollution (CLRTAP) with the objective to minimise or avoid a negative impact of air emissions on the environment and human health. As part of this convention, also known as the 1979 Geneva Convention, Austria signed the Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone on 1 December 1999.

The Protocol sets emission ceilings for 2010 and came into force on 17 May 2005 with Directive 2001/81/EC, also called the NEC Directive (National Emission Ceilings). Directive 2001/81/EC of the European Parliament and of the Council determines for all member states individual and binding emission ceilings from 2010 onwards for nitrogen oxides (NO_x), volatile organic compounds other than methane (NMVOC), sulphur dioxide (SO_2) and ammonia (NH_3). The NEC Directive was transposed into Austrian national law in 2003 by the Air Emission Ceilings Act (*Emissionshöchstmengengesetz-Luft* (EG-L, Federal Law Gazette I No 34/2003)).

The database on national emission ceilings (NEC) for the four air pollutants sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds other than methane (NMVOC) and ammonia (NH_3) used to meet the reporting obligation subject to Directive 2001/81/EC is the Austrian Air Emission Inventory (*Österreichische Luftschadstoff-Inventur* (OLI)), which is carried out annually by the Environment Agency Austria (*Umweltbundesamt*).

In May 2012 a revision of the Gothenburg Protocol[23] was adopted with new reduction targets for 2020. The national targets for 2020 – reference year is 2005 – are: NO_x: – 37%, VOC: – 21%, SO_2: – 26%, NH_3: – 1%, $PM_{2.5}$: – 20%. The reduction targets are not binding, since Austria has not ratified the Gothenburg Protocol. [24]

Emission ceilings pursuant to Air Emission Ceilings Act (*Emissionshöchstmengengesetz-Luft* (EG-L))

Pursuant to Article 2 of the NEC Directive the report obligation covers emissions in the territory of the member states.[25] These emission quantities are Austria's official inventory data pursuant to Article 8 (1) of the NEC Directive:

[23] http://www.unece.org/env/lrtap/multi_h1.html

[24] ENVIRONMENT AGENCY AUSTRIA (*UMWELTBUNDESAMT*) (2014b), p.25

[25] Thus any quantities of pollutants emitted in another country coming from fuel bought in Austria are not taken into account in the transport sector.

	Emissions in thousand tonnes [Gg]			
	SO_2	NO_X	NMVOC	NH_3
1990	73.7	181.5	272.9	65.5
1995	46.5	162.9	224.0	71.3
2000	31.1	163.4	175.3	65.1
2001	32.0	164.9	173.6	64.6
2002	30.5	162.0	172.3	63.3
2003	31.1	165.2	168.8	62.9
2004	27.4	164.3	150.5	62.1
2005	27.1	167.7	158.7	62.0
2006	28.1	167.6	169.9	62.0
2007	24.5	164.0	156.6	62.9
2008	22.1	158.9	148.1	62.3
2009	17.4	146.1	119.6	63.1
2010	18.7	144.0	131.6	62.2
	Emission ceilings in thousand tonnes [Gg]			
2010	39.0	103.0	159.0	66.0

Table 7: National emissions according to the NEC Directive

From 2010 onwards Austria has had to meet an emission ceiling of 103 kt per year for nitrogen oxides (NO_x) according to the Air Emission Ceilings Act (EG-L, *Emissionshöchstmengengesetz-Luft*). However, this emission ceiling was not met in 2010.

In order to meet the NEC targets according to the EG-L (Art. 6) a national action plan was worked out and handed over to the European Commission in February 2010. The implementation and effectiveness of the action plan were analysed by the Environment Agency Austria (*Umweltbundesamt*) in the course of its “NEC Programme Implementation Report” (*NEC-Programm Umsetzungsbericht*).[26]

Reasons for failure

“The resolution of the Directive 2001/81/EC was inter alia based on the assumption that emission regulations for motor vehicles, which were decided on at Union level, will contribute significantly to meeting the emission ceilings of the member states. After 2000 it gradually became clear that the regulations show insufficient effectiveness. Therefore some member states had difficulties in meeting their national emission ceilings and some did not manage them at all, since on a national level no equivalent measures are possible for reducing emissions of the vehicle fleet. The Directive, however, does not provide for any compensatory mechanisms. The Commission was very late (after 2010) with starting work on concrete measures for improving emission behaviour of vehicles. These measures have not yet been decided on and it can be expected that they will only become effective

[26] EVIRONMENT AGENCY AUSTRIA (*UMWELTBUNDESAMT*) (2014b), p.25 et seq.

at the end of this decade. The lack of corrective options means in this case that the consequences of failures of Union law are passed on to the member states."

The problems were caused by the assumptions made when setting the emission ceilings, which were too optimistic from today's point of view or deviated greatly from later developments. The Directive did not provide for any corrective options for this scenario, though.

The main problem of the transport sector, therefore lies in the number of new registrations of diesel passenger cars which was much higher than the projections - the basis for the target agreement - made at that time. Furthermore, diesel passenger cars emit much more NO_x under real-world conditions than expected. This is seen as a consequence of the Union's efforts to achieve a high level of fuel efficiency. CO_2 emission control was achieved but to the disadvantage of NO_x emissions.[27]

4.7 Development of NO_x Emissions in Transport – Assumptions and Development of Real-World Emissions

A study[28] of the IVT – the Institute of Internal Combustion Engines and Thermodynamics at Graz University of Technology investigated how high the NO_x emissions of the transport sector would have been with the activities (mileage) of the current air emission inventory, calculated on the basis of the emission factors of HBEFA V 1.2 (published in 1999). The 1999 version of HBEFA presumed that real-world emissions of the vehicles would exceed the test results; however, it also presumed that the reduction rate would be similar to the reduction of the NO_x limits.

With this assumption, NO_x emissions in 2010 would have been about 25 kt less than real-world emissions. In 2010, 144 kt of NO_x were emitted in Austria and hence the target was exceeded by 31 kt. The main part – almost 80% - of national excess emissions is thus a result of the divergence between real-world emissions and test emissions of vehicles.

The figure below shows the divergence between the reduction in emissions expected at that time and real-world emissions.

[27] BORKEN-KLEEFELD, J. (2012)

[28] REXEIS/SCHWINGSHACKL/HAUSBERGER (2014)

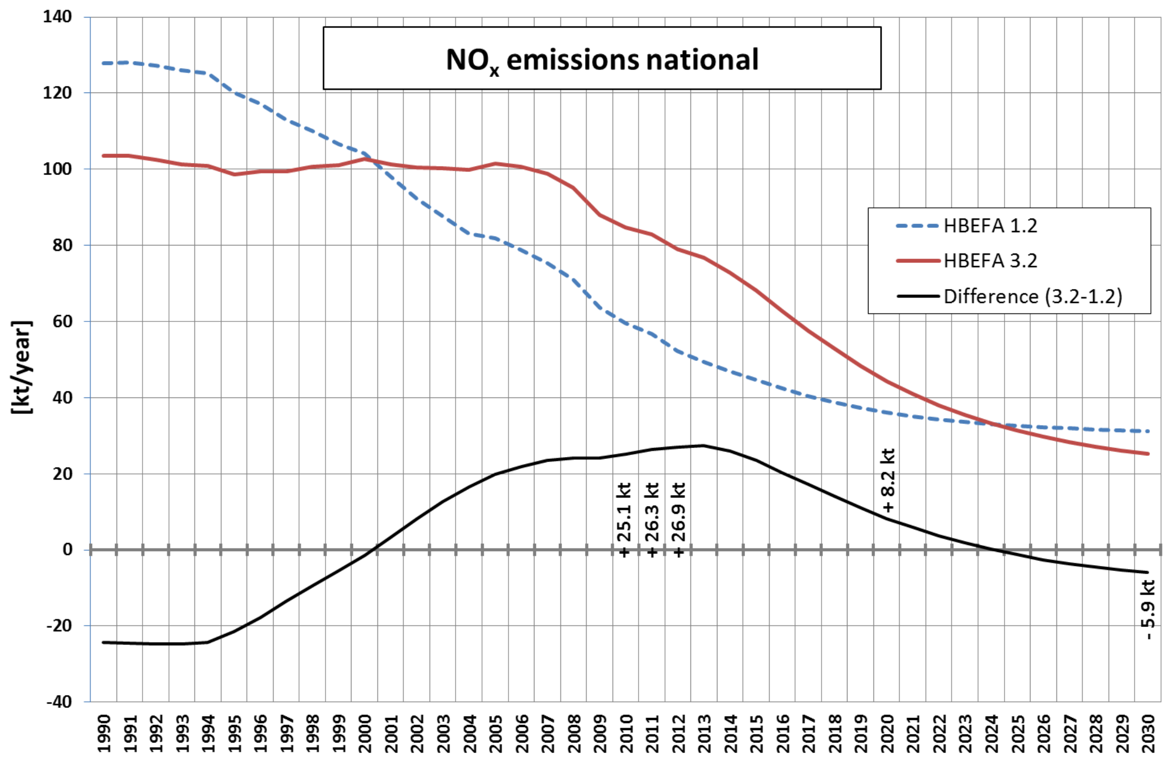

Figure 24: NO_x emissions of the transport sector calculated on the basis of HBEFA 1.2 and HBEFA 3.2

4.8 External Costs

A monetary assessment of the environment and environmental qualities arose from the attempt to estimate the negative effects of human action – in this case traffic – on the environment in units of value. Such environmental units of value are necessary in the field of traffic when it comes to economic efficiency considerations in planning decisions (cost-benefit analysis) or price decisions (taxation and tolls) and should result in better decisions by taking the external effects of the transport sector into account.

External effects are effects which are caused by the behaviour of one or more individuals and do not have an impact only on the individual(s) showing the behaviour, but (also or only) on other individuals. External costs are also not compensated by considerations. Negative external effects or external costs are unwanted effects for the individuals concerned.

Damage costs

The monetary assessment is directly derived from resource consumption and is based on the quantitative relation between the impact of traffic and the damage caused by it. The costs are calculated directly based on the damage actually done, which is assessed with market prices for resources used or lost (e.g. material costs, salaries and interest rates). In such a way a reference value is calculated. The damage costs' approach is often applied for assessing environmental or accident costs (e.g. environmental costs are calculated by assessing damage done to health by emissions caused by traffic).

In the “Handbook of External Costs of Transport”[29] the damage costs for NO_x in the European Community are stated as € 17,285 per tonne (2010). For the target year of the NEC Directive (2010), the difference between real-world emissions and overall emissions in transport calculated on the basis of emission factors without test cycle adjustments amounts to 25.1 kt (see Figure 24: NOx emissions of the transport sector calculated on the basis of HBEFA 1.2 and HBEFA 3.2). This difference would equal additional damage costs of about € 438 m for 2010.

4.9 Possible Impact on Air Quality

It is difficult to assess the impact of higher real-world emissions on air quality in Austria, since the precise effects need to be known without significant real-world emission divergences and especially since the local climatological situation has a significant impact on local air quality and thus on the local pollution level.

In the “Nitrogen oxide immissions at the measurement point Vomp: Scenarios for the years between 2015 and 2020” (“*Stickstoffoxidimmissionen an der Messstelle Vomp: Szenarien für 2015 – 2020”) (ÖKOSCIENCE 2015)*) report, the effects of different measures to reduce NO_x emissions are analysed on the Inntalautobahn motorway. One scenario (Scenario M6) analyses what effects would be expected if the Swiss fleet was to drive on the A 12 motorway instead of the Austrian fleet. Switzerland has a much lower share of diesel vehicles; hence this scenario approximately shows the effect of a fleet having diesel vehicles (especially Euro 3 - 5) with significantly reduced emissions in real-world driving.

The scenario was calculated with a share of diesel vehicles of 33% (as in Switzerland). Such a fleet composition is more effective regarding air quality at the measurement point Vomp (close to the motorway) than all measures which were either discussed or implemented in Tyrol (permanent speed: 100km/h, ban on semi-trailers Euro III, ban on solo lorries Euro II and III, ban on heavy-duty vehicles on certain sections of the motorway). The result is a reduction of approx. 9°µg/m³ NO_2 compared to the reference scenario 2012 down to 55.3 instead of 63.9°µg/m³ NO_2.

This is a reduction in NO_2 pollution of 15%. This effect was only analysed and calculated for the measurement point Vomp A12 and its special situation regarding pollution and proliferation, however, it shows the massive impact of diesel NO_x emissions on air quality especially close to roads. A reduction in real-world NO_x emissions corresponding to a reduction in the limits in recent decades would have significantly reduced the need for traffic restrictions such as vehicle bans or speed limits for better air quality.

[29] EC – EUROPEAN COMISSION, DG MOBILITY AND TRANSPORT (2014), page 37

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