Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2022) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

Modelling the effects of Euro 7/VII emission standard on road traffic related emissions in Germany

Dr. Conrad Piasecki[a]

[a]*Federal Highway Research Institute (BASt), Bruederstraße 53, 51427 Bergisch Gladbach, Germany*

Abstract

Road traffic represents a significant source of air pollution and greenhouse gas emissions, particularly in urban areas. To face this issue, activities are ongoing at European level to introduce a new emission standard for passenger cars, namely Euro 7. This legislative act aims at improving the air quality situation and thus the prerequisite for human well-being inside the EU. This paper focusses on the evaluation of the effectiveness of Euro 7 emission standard with regard to vehicle fleet emissions in Germany. To this end, emission trend scenarios were generated in order to simulate the emission reduction potential of Euro 7 by applying the TREMOD model. Varying reduction potential becomes apparent depending on the emission component in concern. Assumptions laid down in this study need to be verified with real-world emission data when the new emission standard comes into force.

Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference
Keywords: Euro 7/VII; air pollution; TREMOD; emission simulation

1. Introduction

Motorized vehicles equipped with combustion engines are substantial actors in terms of air quality problems, particularly in urban areas [1]. Exhaust gas components like, among others, nitrogen oxides (NO_X), particles (PM) and unburned hydrocarbon fractions (HC) are classified as toxicologically affective on the human organism as they are absorbed via the lung system and potentially enter the bloodstream circulation [2] [3]. Additionally, certain substances in the exhaust gas act as precursors for chemical conversion processes in the ground level atmosphere and lead to the formation of partly harmful gases such as ozone (O_3). Health impairments, increasing economic costs and ongoing damage to ecological systems are a consequence of an exposure to such pollutants [4].

Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference

To this end, the European Commission (EU-COM) intends to restrict negative environmental effects caused by motor vehicles by introducing a new emission standard, namely Euro 7/VII. The implementation of the new Euro 7/VII regulation is planned for the year 2025 – according to the current status of the ongoing process – and it applies to passenger cars and light- and heavy duty vehicles (hereinafter, only "Euro 7" is mentioned, since Euro VII refers to the commercial vehicle sector, which is not a subject within this study). Besides a progressive reduction in tailpipe emission limits, emphasis is given to additional aspects like, among other things, the cold start emission behavior, evaporative emissions and the regeneration characteristics of particle filters. The Euro 7 standard represents another noticeable step in the mitigation strategy of air- and environmental related pollution induced by the traffic sector. A significant tightening of environmental standards compared to the current Euro 6 legislation is expected. Various technical details of the Euro 7 norm have been elaborated by a scientific consortium (CLOVE - *Consortium* for ultra Low Vehicle Emissions), which was commissioned by the EU-COM consisting of universities, emission laboratories and independent experts from across Europe. The progress and results from CLOVE have been presented regularly in AGVES[1] meetings (Advisory Group on Vehicle Emission Standards), where national representatives, NGO's, automotive manufacturers and suppliers joined to discuss the ongoing process. Results from this group have been made available to the public sector continuously [5].

In this content, the question arises how effective the Euro 7 legislative package is concerning its emission reduction potential, particularly, with regard to the challenging situation in different countries and cities affected by a poor air quality situation. Estimating the prospective development of harmful pollutant concentrations in pressurized areas due to potential emission savings is certainly difficult, as the local air quality situation is determined by a variety of parameters. Complex chemical conversion processes in the ground-level boundary layer, local topography effects, weather and wind conditions as well as background pollutant concentrations from other sectors (e. g. industry, energy sector) are relevant in this context.

Within the scope of this study, the reduction potential of exhaust gas emissions due to the Euro 7 emission standard is calculated by means of simulation for the passenger car fleet in Germany. The governmental-wide accepted emission calculation model TREMOD (Transport Emission Model) is applied for the baseline vehicle fleet emission simulations [6]. Emphasis is given to the generation of trend scenarios for currently regulated exhaust gas components, namely carbon monoxide (CO), nitrogen oxides (NO_X), hydrocarbons (HC) and particulate matter (PM). Climate change affecting gases like carbon dioxide (CO_2) and methane (CH_4) are no subject within this study – on the one hand because CO_2 is not regulated so far on the vehicle side (fleet target values exist instead), and because no previous emission limit values exist for methane.

In a first step, the expected vehicle fleet composition and underlying annual traffic data of prospective Euro 7 vehicles are determined up to 2035 based on market ramp-up functions and mileage-age relations in TREMOD. Based on the intended emission limits as proposed by CLOVE, emission factors for Euro 7 approved vehicles are derived. These data sets form the basis for the simulations of the emission saving potential for different exhaust gas components.

2. **Methodology and results**

The assessments of Euro 7 emission standard on German fleet emissions is carried out by using the TREMOD model. TREMOD is a macroscopic emission calculation model that calculates vehicle fleet emissions in a high degree of differentiation (e. g. according to vehicle segments and technology standards, emission components and local area). The development of TREMOD was initiated on behalf of the German Federal Environment Agency (UBA) in the 1990's in order to query detailed information concerning fleet emissions, activity and fuel- and energy consumption

*[1]The activities within the AGVES group are completed with the final presentation of the proposal of the CLOVE consortium. The legislative proposal of the EU-COM on Euro 7/VII based on CLOVE's elaborations is expected in summer 2022.

data in the field of transport in Germany [7]. Accepted for the emission inventory process in the EU, almost all relevant modes of transport are covered, namely road-, air-, rail- and inland waterway transport. The road traffic sector is implemented in particularly high resolution due to the relevance of motorized traffic as a substantial source for urban air quality problems. Retrospective emission- and energy investigations are feasible back to the year 1960; future trend scenarios are implemented up to the year 2050 in the latest TREMOD version 6.21 applied within the study at hand. TREMOD is used by several governmental institutions for analysing environment related issues and, additionally, some private associations and companies like the German car manufacturer association (VDA) and the Deutsche Bahn AG deal with TREMOD in certain applications. The model is adjusted annually by the IFEU Institute (Institute for Energy and Environmental Research) and extended with emission-, traffic- and vehicle fleet related data sets of newly introduced vehicles, which are finally linked in complex calculation routines [8]. Emission factors are adopted directly from the Handbook Emission Factors of Road Transport (HBEFA) that represents the European wide standardized database for real-world emissions in the traffic sector. Vehicle fleet data is provided by the German Federal Motor Transport Authority (KBA) [9]. Annual traffic data is generated as part of fixed camera-based traffic monitoring stations, odometer readings during periodic technical inspections (PTI) and in the context of driving performance surveys that are initiated regularly in Germany, in which traffic data sets for all relevant vehicle categories are collected in a high degree of differentiation [10] [11]. Complementary studies such as market analyses from the German Institute of Economic Research (DIW) and market monitorings performed by the Federal Office for Freight Transport (BAG) are considered for traffic data validations, and that are combined into a consistent traffic module in TREMOD [12] [13]. Since only road traffic related investigations are carried out within the framework of this study, all further remarks to TREMOD refer to the road traffic module.

The prediction of passenger cars fleet emissions is based, among others, on estimations concerning the vehicle fleet development and -composition after the introduction of Euro 7 in 2025. To this end, registration numbers of present vehicles (Euro 6 approved) in conjunction with so-called survival curves, that describe the share of vehicles eliminated from the market over time, form the basis for future fleet simulations in TREMOD. As a result, a market ramp-up of Euro 7 passenger cars can be designed in a trend scenario – differentiated according to emission standards (a) and propulsion technology (b), as presented in figure 1.

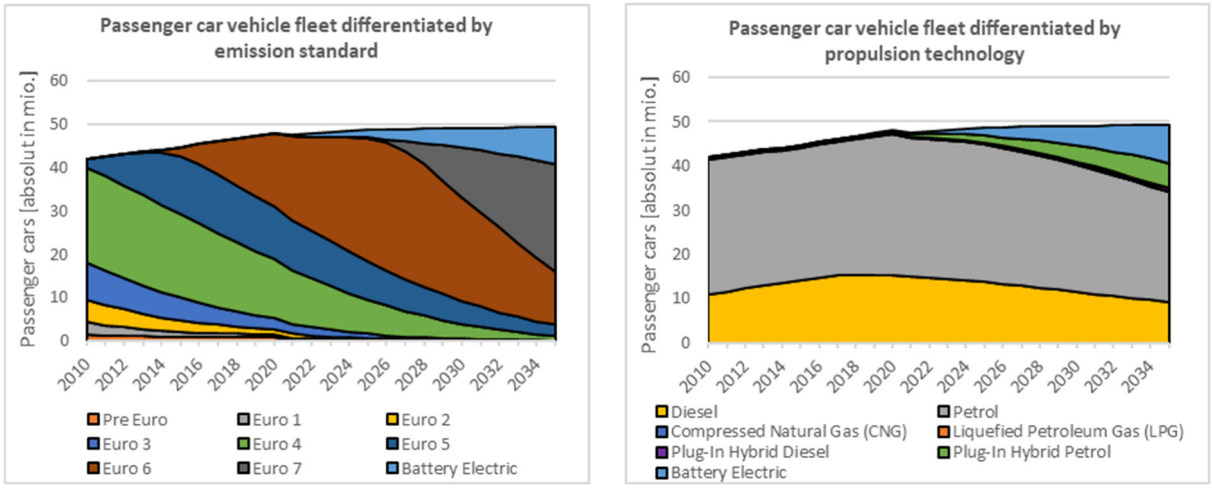

Fig. 1: Market ramp up of Euro 7 passenger cars in Germany: differentiated according to emission standards (a) and according to propulsion technology (b).

According to figure 1 (a), there are approximately 47 mio. passenger cars registered in Germany in 2022. The overall fleet is deemed to increase slightly by 2035. From 2025 onwards, Euro 7 approved vehicles will enter the market and reach a market share of approximately 50 % by 2035. Taking into account the expected fleet distribution by propulsion type, a noticeable shift towards alternative propulsion technologies becomes apparent – particularly,

battery electric vehicles (BEV) and plug-in hybrid vehicles (PHEV) are increasingly gaining market shares and will make up to about 30 % by 2035. Accordingly, the market shares of conventionally powered vehicles (diesel and petrol) are steadily declining over the same period. The development of the vehicle fleet is affected, among other things, by governmental promotion programs and subsidization effects of certain technologies – both, on national level and on EU-level. Political framework conditions might change over time and finally steer the development of the vehicle fleet composition in various directions. In addition, possible supply chain interruptions in automotive manufacturing might delay vehicle deliveries - e. g. as a consequence of the global corona pandemic situation – and cannot be reflected seriously in future TREMOD scenarios.

Besides the prospective vehicle fleet development, information on annual traffic data is an important parameter for TREMOD-based vehicle fleet calculations. The traffic shares of Euro 7 approved vehicles are calculated accordingly. To this end, traffic shares of Euro 6 vehicles are shifted towards Euro 7 vehicles taking into account mileage-age-relations applied in TREMOD (description of the decline of annual traffic shares with increasing vehicle age) and empirical data on earlier market ramp-ups. This procedure results in the annual traffic distribution as shown in figure 2 – once, differentiated by emission standard (a) and once by propulsion technology (b).

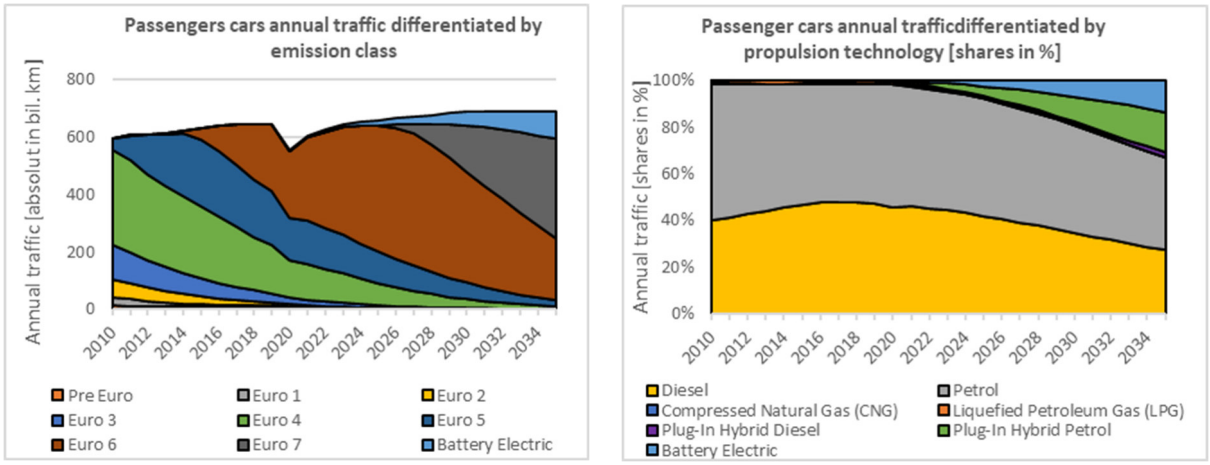

Fig. 2: Passenger cars annual traffic in Germany: differentiated according to emission standards (a) and according to propulsion technology (b).

Figure 2 indicates a steadily increase in total passenger cars annual traffic over the period under review – from approximately 600 billion km in 2010 to approximately 700 billion km per year in 2035. The annual traffic development is almost proportional to the vehicle fleet trend scenarios in terms of market ramp-up of alternative propulsion technologies and according to annual traffic differentiated by emission standards. In 2020 the decline in annual traffic due to the corona pandemic situation and the following rapid recovery from this one-off effect becomes apparent. This effect is more pronounced in terms of newly registered vehicles (Euro 6), since these are rather intended for daily use and commuting purposes, which was particularly affected during the early phase of the pandemic (in terms of nationwide lockdowns). In 2022, an annual traffic situation similar to the pre-pandemic level is achieved according to TREMOD.

In a further step, an estimation of the real-world emission factors of Euro 7 vehicles as input parameters for TREMOD calculations is carried out. An assessment of future emission factors for relevant components in concern - namely NO_X, HC, CO and PM - based on earlier emission stages, real-world fleet emission developments and based on future emission limit values as proposed by the CLOVE consortium seems appropriate. To this end, the average fleet emission factors – indicated in g/km - of vehicles fulfilling the current emission standard (Euro 6) are considered and the difference to the existing limit values is determined. It is assumed that the gap between the average fleet emission values of Euro 7 approved vehicles and the underlying Euro 7 limit values is accordingly pronounced. Based on these assumptions, the vehicle fleet emissions of Euro 7 vehicles are calculated in TREMOD

The reduction in emission limit values for relevant pollutant components that are investigated in the framework of this study is presented in figure 3. The limit values are adopted from the latest proposal of the CLOVE consortium and they are compared to the current limit values of Euro 6 emission standard. A distinction is made between limit values for petrol and diesel vehicles and, additionally, CLOVE has developed two different possible scenarios for future limit values - a lighter and a heavier stage, referred here as scenario 1 and scenario 2 [5]. The underlying boundary conditions for emission measurement runs with PEMS systems - portable emission measurement system applied for on-road emission recording – are intended to be adjusted. Hereby, almost all possible engine load and driving conditions within the emission measurement procedure (e. g. strong accelerations, uphill-driving, heavy loads etc.) should be reflected.

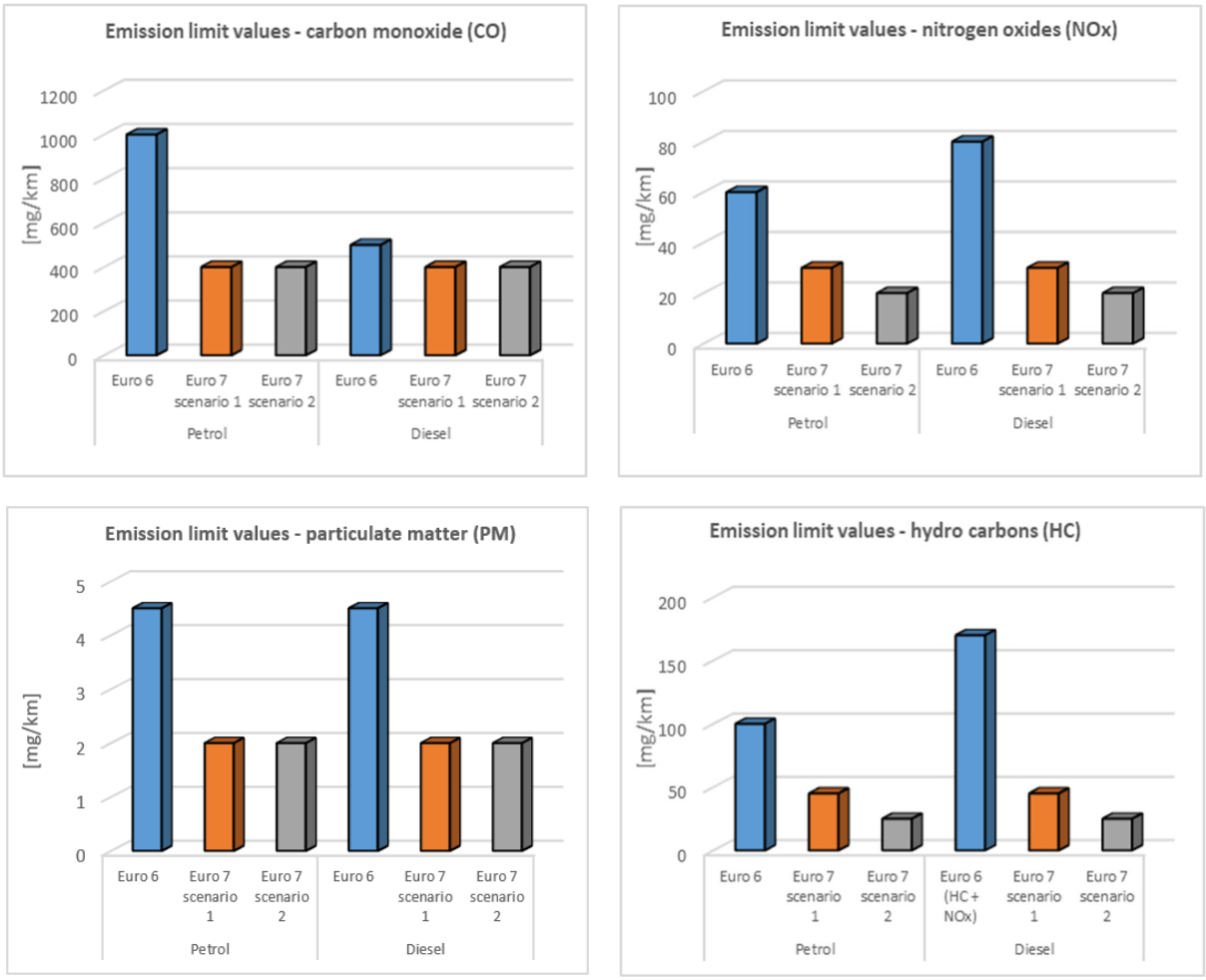

Fig. 3: Proposed Euro 7 emission limit values for NO_X, CO, PM and HC in contrast to the Euro 6 emission standard – differentiated according to petrol and diesel vehicles and according scenario 1 and scenario 2 as proposed by the CLOVE consortium.

Finally, figure 4 shows the vehicle fleet emission development of the passenger car segment in Germany for relevant exhaust gas components up to the year 2035. The trend scenario calculations include the introduction of Euro 7 emission standard from 2025 onwards – emission limits according to CLOVE proposal scenario 2 - and the associated savings in fleet emissions (red shaded area in the diagrams) compared to the baseline scenario, in which no further limit reductions after Euro 6 are assumed. All emission quantities are indicated in tons per year and relate to Germany in total; a further distinction according to local areas and street level is not carried out in this study. In

principle, all emission trend scenarios elaborated in this work show a strong decrease up to the year 2035. This effect is primary based on the renewal of the entire vehicle fleet, in which older vehicles are replaced by newly approved ones with a generally enhanced emission behavior. Depending on relevant emission components in question, a diverging reduction potential for the passenger car fleet becomes apparent, see table 1. NO_X emissions are deemed to decrease by -84 % from 2022 up to 2035 considering the implementation of Euro 7 – without taking into account the new legislation, a decrease of approximately -76% would be achieved. One can deduce from this matter, that Euro 6 emission standard already achieves an appropriate reduction of NO_X emissions under real driving conditions compared to previous limit stages, which is finally reflected in fleet development.

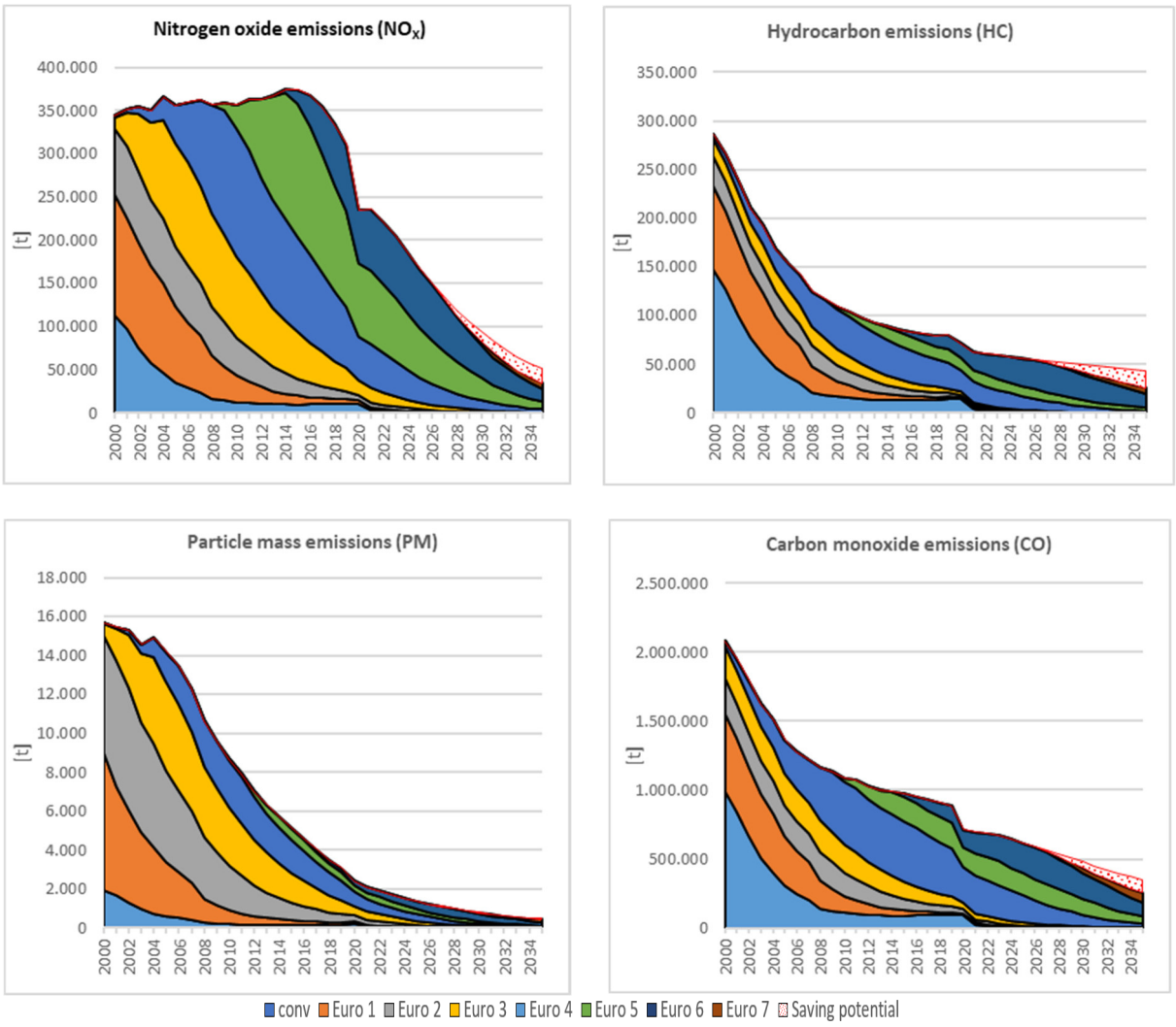

Fig. 4: Vehicle fleet emission development of passenger cars in Germany up to 2035 differentiated by emission component including Euro 7 standard – saving potential.

Table 1: Passenger car fleet emission reduction potential for different emission components up to 2035.

	NO_X	CO	HC	PM
Reduction potential up to 2035 (without Euro 7)	-76%	-48%	-28%	-68%
Reduction potential up to 2035 (including Euro 7)	-84%	-62%	-57%	-77%

As indicated in table 1, HC and CO savings due to Euro 7 turn out to be higher pronounced (compared to the scenario in which no Euro 7 comes into force) in contrast to NO_X emissions, as one legislative intention is to focus on reducing cold-start emissions after engine starts, which particularly affects HC and CO. As a consequence of significantly reduced limit values and based on so-called cold start budgets, which automotive manufacturers have to comply with within the new test procedure, it is assumed that the highest reduction potential in HC and CO emissions due to Euro 7 is related to cold start savings, which can be found primarily in urban areas. Hereby, noticeable mitigation effects concerning the air quality impairment in residential areas are expected. Particulate matter emissions (PM) are deemed to decrease only slightly in the trend scenario calculation due to the introduction of Euro 7. Vehicle fleet emissions will decrease approximately about -77% up to 2035 considering Euro 7 legislation, while the decline is already about -68% without considering the new emission standards after Euro 6. One reasons for this issue is that particle mass emissions were already widely reduced by the mandatory introduction of particle filter systems in diesel driven vehicles in 2009. To this end, vehicle types registered from 2009 onwards show very low particle mass emissions, which is finally reflected in the trend scenario results here. In this context, Euro 7 places emphasis on reducing particle number emissions (PN) more stringently instead, particularly by considering and evaluating filter regeneration phases within the measurement procedure

3. **Summary and outlook**

The TREMOD trend scenario calculations carried out in this study indicate varying reduction potentials for different exhaust gas components of passenger cars in Germany due to the introduction of Euro 7. Overall, a significant reduction in vehicle fleet emissions in the passenger car segment can be expected, however, this is predominantly based on a general renewal process of the entire vehicle fleet. The extent to which the change in fleet emissions will affect the air quality situation in urban areas - which is the primary concern of Euro 7 legislation - cannot be predicted precisely, since interactions with other relevant sector emissions and local circumstances have to be taken into account. In particular, chemical interactions of certain air pollutants show a significant influence concerning the air-quality side. In general, it is important to note, that forecasts over such a long period may be subject to short-term fluctuations that are almost unpredictable, as the corona pandemic situation has revealed. In addition, unexpected technological achievements in automotive engineering or concerning the infrastructure side may lead to varying emission characteristics and ultimately to diverging fleet emissions. As far as Euro 7 compliant vehicles are available on the market, emission measurement campaigns need to be carried out in order to validate the emission factor database in models like TREMOD and HBEFA in order to ensure robust calculation results. This should be accompanied by updated annual traffic- and vehicle fleet data sets as required for calculation processes in TREMOD.

References

[1] Stohl, A.: Intercontinental Transport of air pollution – The handbook of environmental chemistry. Berlin, Heidelberg, 2004.

[2] Buckeridge, D. L., Glazier, R., Harvey, B. J., Escobar, M., Amrhein, C., Frank, J.: Effect of Motor Vehicle Emissions on Respiratory Health in an Urban Area. Environmental Health Perspectives, Volume 110, Number 3, March 2002.

[3] Chen, G., Wan, X., Yang, G., Zou, X.: Traffic-related air pollution and lung cancer: A meta-analysis. Thoracid cancer (6), 2015.

[4] Brunekreef, B., Beelen, R., Hoek, G., Schouten, L., Bausch-Goldbohm, S., Fischer, P., Armstrong, B., Hughes, E., Jerret, M., van den Brandt, P.: Effects of Long-Term Exposure to Traffic-Related Air Pollution on Respiratory and Cardiovascular Mortality in the Netherlands: The NLCS-AIR Study. HEI Research Report 139, Health Effects Institute, Boston, MA. 2009.

[5] https://circabc.europa.eu/sd/a/83a09cc8-7f8f-4ca6-9764-0b77da57d4cc/AGVES-2021-04-08-LDV_Exhaust.pdf

[6] Transport Emission Model; Version 6.21, 31.01.2016. Developed by ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, Im Weiher 10, 69121, Heidelberg, Germany. Copyright by UBA – Umweltbundesamt Germany, D-06813 Dessau, Germany.

[7] Knörr, W., Heidt, C., Schacht, A.: Aktualisierung ”Daten- und Rechenmodell: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2030“ (TREMOD, Version 5.3) für die Emissionsberichtserstattung 2013 (Berichtsperiode 1990-2011). Heidelberg, 30.09.2012.

[8] Bergk, F., Heidt, C., Knorr, W. (IFEU) Keller, M. (INFRAS AG). Erweiterung der Software TREMOD um zukünftige Fahrzeugkonzepte, Antriebe und Kraftstoffe. Endbericht. Im Auftrag der Bundesanstalt für Straßenwesen (BASt). 30.09.2014.

[9] Keller, M., Wuthrich, P., Notter, B.: HBEFA - Handbook emission factors for road transport 3.1 / 3.2/ 3.3. Quick reference. Bern, April 24, 2017.

[10] Richtlinien für die Straßenverkehrszählung im Jahre 2015 auf den Bundesfernstraßen. Bundesministerium für Verkehr und digitale Infrastruktur, Referat StB 11.

[11] Baumer, M., Hautzinger, H., Pfeiffer, M., Stock, W., Lenz, B., Kuhnimhof, T., Kohler, K. Fahrleistungserhebung 2014 – Inlandsfahrleistung und Unfallrisiko. Berichte der Bundesanstalt für Straßenwesen, Unterreihe V „Verkehrstechnik“ Heft V 291, Bergisch Gladbach, August 2017.

[12] Kalinowska, D., Kloas, J., Kuhfeld, H., Kunert, U.: Aktualisierung und Weiterentwicklung der Berechnungsmodelle für die Fahrleistungen von Kraftfahrzeugen und für das Aufkommen und für die Verkehrsleistungen im Personenverkehr (MIV). Gutachten. Im Auftrag des Bundesministeriums für Verkehr, Bau- und Wohnungswesen. Endbericht. Berlin, April 2005.

[13] Bundesamt für Güterverkehr: Marktbeobachtung Güterverkehr. Jahresbericht 2013. Köln, Juni 2014.