Guidebook updates

Chapters 1.A.3.b.i-iv / Road Transport

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New elements in 2019

- Revision of emission factors for mopeds and motorcycles

- Calculation of the fossil fuel fraction in biodiesel

- Revision of Euro 6 evaporation emission factors

- Revision of Euro 6 LCVs emission factors

- Review of exhaust NMVOC speciation profile

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Emission factors update: Mopeds & Motorcycles

Test campaigns

- New tests in the framework of the ERMES-ACEM study (2018)
  - Sample: 3 mopeds and 15 motorcycles
  - Technology: Euro 4
  - Lab: JRC, TUG and FHB

- Tests in the framework of the L-category Euro 5 Effect Study (2017)
  - Sample: 41 vehicles
  - Technology: Euro 1 to Euro 4
  - Lab: JRC (mostly) and LAT

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- Tests on mopeds in the Netherlands (2017)
  - Sample: 15 mopeds
  - Technology: Euro 2 and Euro 3
  - The measurement programme was set up by TNO

- Tested driving cycles:
  - WMTC, ECE R40, ECE R47, WOT, IUC, AMA, SRC-LeCV, FHB1, FHB2, FHB3, FHB4, RCC, RDC1, RDC2, RDM

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Methods: mopeds

- Euro 3
  - Based on the data from the TNO study *(data from the Euro 5 Effect study have been used only for verification)*
  - Based on the driving cycle: ECE R47

- Euro 4
  - Based on the data from the ERMES-ACEM study
  - Based on the driving cycles: ECE R47 and RDM

Methods: motorcycles

- Technology: Euro 3 to Euro 5

- Pollutants: CO, VOC, NO_x and energy consumption

- Motorcycle classes: 2-stroke, 4-stroke <250 cc, 4-stroke 250-750 cc, 4-stroke >750 cc

- Calculation steps

  - Step #1: the measurement data have been processed by TUG, providing the emission factors of HBEFA v4.1

  - Step #2: regression analysis: Levenberg-Marquardt (LM) algorithm for non-linear curve-fitting of data, using the robust least absolute residuals (LAR) fitting method
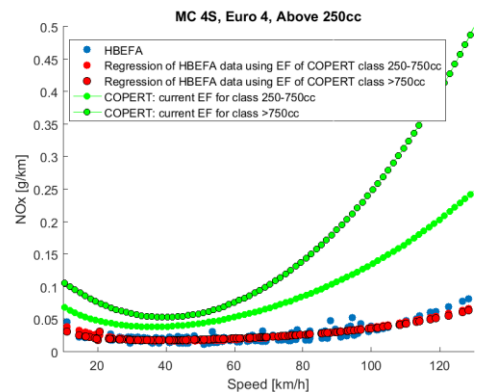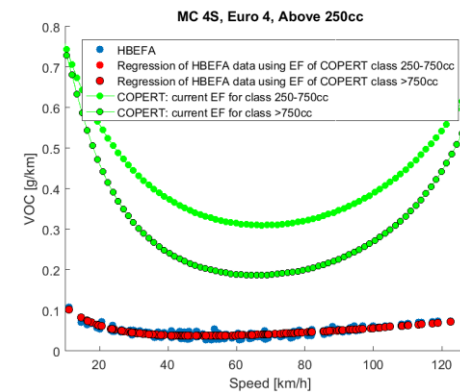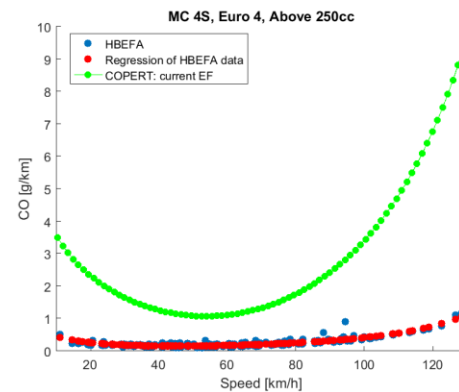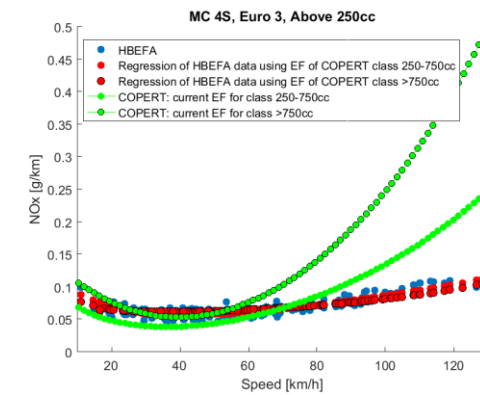
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Emission factors

- ## Mopeds:

| Euro	Driving Mode	CO [g/km]	VOC [g/km]	NO$_x$ [g/km]	PM (exhaust) [mg/km]	PN [#/km]	CO$_2$ [g/km]	FC [l/100km]
Euro 3	Urban	3.9	1.8	0.39	8.4	2.3E+12	41.3	2.3
	Rural	2.0	1.0	0.36	6.5	2.3E+12	44.1	2.1
Euro 4	Urban	2.4	0.5	0.05	2.1	-	46.5	2.2
	Rural	2.0	0.4	0.04	1.5	-	46.4	2.2

- ## Motorcycles:
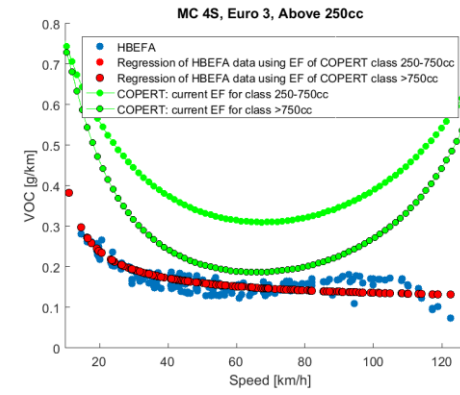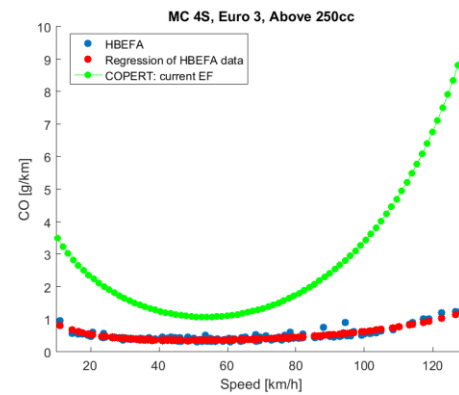
Calculation of the fossil fuel fraction in biodiesel

Why this update?

- Assessment of biodiesel origin: Identify & separate biogenic and fossil feedstock involved in the production process. E.g. biodiesel from coal methanol with vegetable oil has a non-zero fossil fuel fraction, thus not entirely carbon neutral fuel

- Depending on the production pathway, fossil fuel carbon content is about 5.5%

- Aim: Calculation of fossil fuel carbon content of biodiesel deriving from the most widely used production pathways

Source: https://www.e-education.psu.edu/egee439/node/684
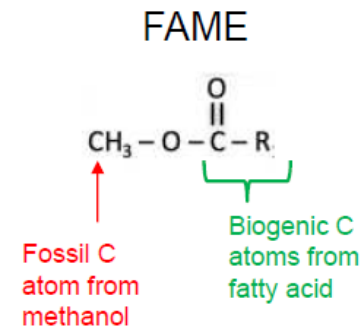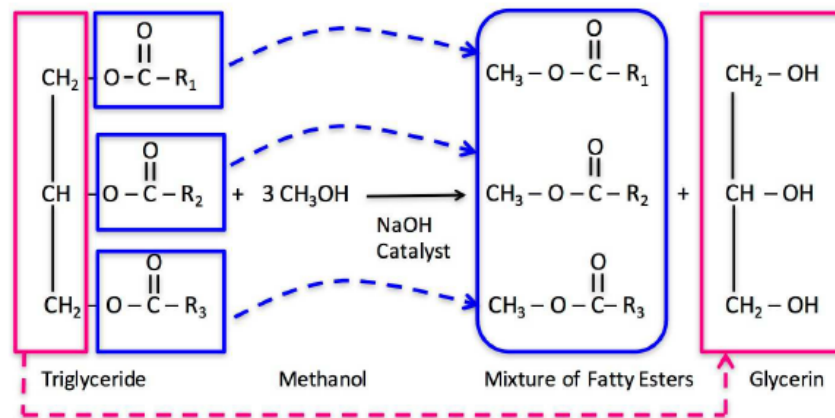
Fossil and biogenic CO_2 emissions to FAME

- Fossil origin g CO_2 / g FAME = (carbon content of FAME) * (fossil part of C of FAME) * 44/12

- Bio origin g CO_2 / g FAME = (carbon content of FAME) * [100% - (fossil part of C of FAME)] * 44/12

	C fossil part	Carbon content	g fossil CO_2 / g FAME
Sunflower	5.3 %	77.2 %	0.150
Rapeseed	5.3 %	75.5 %	0.147
Palm oil	5.5 %	71.8 %	0.145
Cottonseed	5.4 %	77.0 %	0.152
Tallow	5.5 %	73.6 %	0.148
Lard	5.4 %	74.4 %	0.147

New Euro 6d evaporation emission factors

Why this update?

- Regulation (EU) 2017/1221 introduced a new procedure for evaporative emissions, applicable to Euro 6d-temp and Euro 6d vehicles

- Whereas the emission limit remains at 2.0 g of NMVOC per test, the procedure becomes more severe, specifically targeting the aging of the carbon canister and the permeability of the fuel system

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Methodology

- Modelling work carried out in the framework of the "Review of the European test procedure for evaporative emissions | Cost/Benefit analysis" (JRC)

- A number of scenarios developed to assess different policy options

- COPERT model adjusted to simulate the developed scenarios

Scenario 1	Scenario 2	Scenario 3
• More aggressive purging	• More aggressive purging • Bigger canister (size x 2)	• More aggressive purging • Bigger canister (size x 2) • Improved durability (lower carbon degradation) • Multi-layer tanks for all cars

Results

- Stricter procedure in Regulation (EU) 2017/1221:
  - Longer (48 h) diurnal test --> Bigger activated carbon canister
  - Shorter preconditioning time --> More intense purging strategy
  - Stricter aging procedure of the carbon canister --> Low degradation carbon

		Canister size (liters)		Degradation / purging strategy	
		Current (GB 2018)	Suggested (GB 2019)	Current (GB 2018)	Suggested (GB 2019)
Mini & small Passenger Cars (petrol only)	Euro 3 – Euro 6c	0.8	0.8	High degr. / low purge rate	High degr. / low purge rate
	Euro 6d-temp / 6d		1.6		Low degr. / high purge rate
Medium Passenger Cars N1-I, N1-II LCVs (petrol only)	Euro 3 – Euro 6c	1.0	1.0	Low degr. / high purge rate	Low degr. / high purge rate
	Euro 6d-temp / 6d		2.0		
Large Passenger Cars N1-III LCVs (petrol only)	Euro 3 – Euro 6c	1.5	1.5	Low degr. / high purge rate	Low degr. / high purge rate
	Euro 6d-temp / 6d		3.0		

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Revision of Euro 6 LCVs emission factors

Why this update?

- Previous EFs based on assumed developments over previous standards, in line with passenger cars

- New experimental data has become available

- 3 TNO reports:
  - Investigations and real world emission performance of Euro 6 light-duty vehicles (2013 R11891)
  - NOx emissions of Euro 5 diesel vans – test results in the lab and on the road (2016 R10356)
  - NOx emissions of eighteen diesel Light Commercial Vehicles: Results of the Dutch Light-Duty road vehicle emission testing programme 2017 (2017 R11473)

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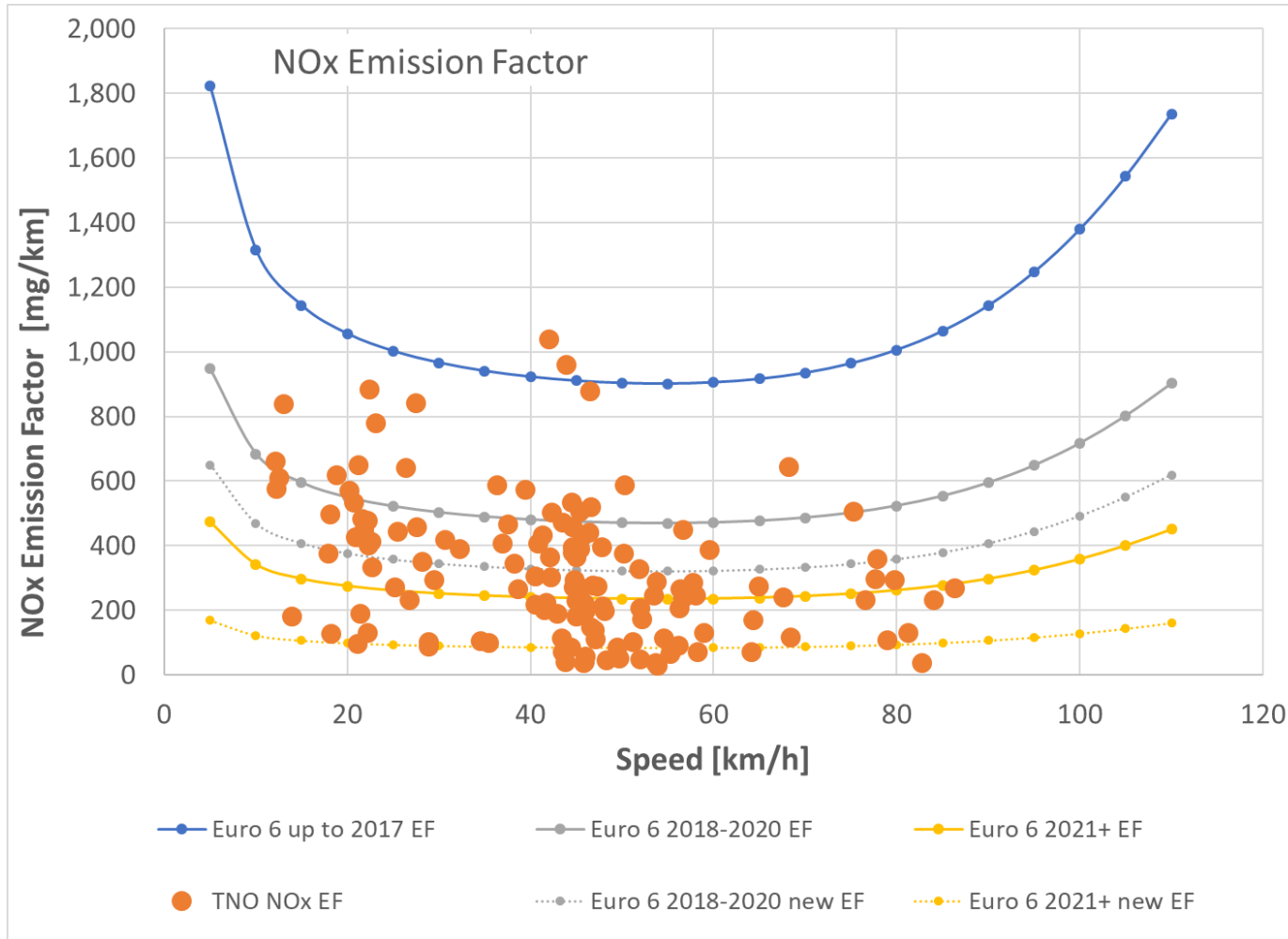
Review of exhaust NMVOC speciation profile

Why this update?

- Outdated speciation data (1989 – 1996)

- No differentiation for Euro standard technology

- No speciation for L-category; assumed same as passenger cars

Extensive literature review conducted to collect latest data on VOC speciation

Vehicle category	Number of studies examined
Passenger cars	7
Light commercial vehicles	2
Heavy duty trucks	2
Motorcylces and Mopeds	3

Limitations:
1. Some references only focus on certain VOC species (e.g. benzene or formaldehyde), therefore a complete VOC profile cannot be extracted.
2. There are studies originated from countries/regions where different emission standards exist (e.g. European standards vs. US standards).
3. Wide range in the publication dates of the references led to different emissions control technologies examined in the references.

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Methodology

Most studies examined focus on VOC pollutant groups (e.g., alkanes, aromatics etc.) and do not provide detailed VOC species. Therefore, a top-down approach has been followed in order to produce a complete VOC speciation profile.

Suggested NMVOC speciation profile

Search for relevant literature

Comparison of VOC profiles at species group level (e.g. alkanes, aromatics etc.)

Selection of the most detailed VOC profile for each vehicle category

Allocation to the detailed VOC species (e.g. ethane) based on the existing Guidebook profile
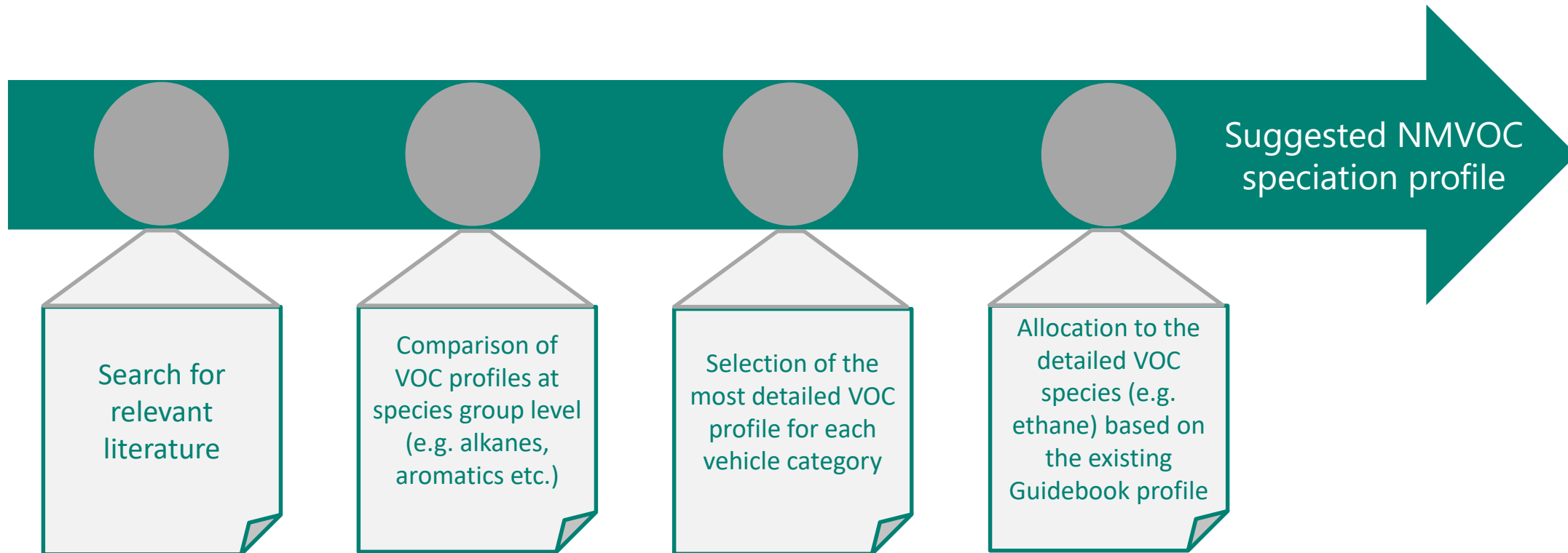
Passenger cars & LCVs

- In most of the studies reviewed for passenger cars, there is either no sufficient breakdown of emission technologies standards, or there are US standards that are generally incompatible with European ones.
- The INRETS study includes results for 30 passenger cars – 13 petrol and 17 diesel – tested using a set of 4 real-world driving cycles.
- **Speciation dominated by aromatics (especially for petrol) → much higher than in other relevant studies**

Passenger cars & LCVs		INRETS 2006, Emissions of unregulated pollutants from European gasoline and diesel passenger cars (Average Urban + Motorway)				Current (GB 2018)		Other studies
		ECE 1504	Euro 1	Euro 2	Euro 3	Pre Euro	Euro 1+	
Petrol	Alkanes	-	4.9%	12.4%	6.5%	17.3%	29.8%	28.4% - 53%
	Cycloalkanes	-	-	-	-	0.9%	1.1%	N/A - 2%
	Alkenes+Alkynes	-	0.6%	1.6%	2.5%	27.6%	20.3%	3% - 29%
	Aldehydes	-	0.2%	0.5%	0.3%	4.3%	3.3%	N/A - 12.5%
	Ketones	-	0.3%	0.2%	0.1%	0.3%	0.7%	N/A - 12.5%
	Aromatics	-	92.9%	82.9%	89.4%	49.6%	44.4%	20.5% - 41.9%
	Alkanes C>15	-	1.1%	2.4%	1.2%	0.0%	0.0%	N/A
Diesel	Alkanes	13.1%	25.6%	13.8%	20.0%	24.5%	24.5%	35%
	Cycloalkanes	-	-	-	-	0.7%	0.7%	N/A
	Alkenes+Alkynes	3.4%	15.9%	4.2%	1.0%	19.5%	19.5%	N/A
	Aldehydes	3.2%	7.6%	1.2%	0.3%	31.1%	31.1%	N/A
	Ketones	0.6%	1.0%	0.6%	0.1%	4.1%	4.1%	N/A
	Aromatics	76.4%	43.8%	76.0%	67.5%	19.5%	19.5%	65%
	Alkanes C>15	3.3%	6.1%	4.3%	11.1%	0.0%	0.0%	N/A

Heavy duty trucks & Motorcycles/Mopeds

Heavy duty trucks

- Two relevant studies examined.

- No further split to emission control standards.

- The **"Volatile organic compounds (VOCs) source profiles of on-road vehicle emissions in China"** study is the most comprehensive and detailed.

Heavy duty trucks	Hongli 2017, Volatile organic compounds (VOCs) source profiles of on-road vehicle emissions in China
Alkanes	50.0 %
Alkenes	15.0 %
Alkynes	3.5 %
Aldehydes	0.0 %
Ketones	0.0 %
Aromatics	31.5 %

Motorcycles & Mopeds

- Three relevant studies examined.

- Suggested values from TNO study **"Emissions of two-wheeled vehicles"** for the VOC profile.

- VOC profiles of this study were derived from literature for mopeds and 4-stroke motorcycles

L-category	TNO 2011, Emissions of two-wheeled vehicles	
	Motorcycles	**Mopeds**
Alkanes	35 %	42.6 %
Alkenes	15 %	17.0 %
Alkynes	5 %	4.8 %
Aldehydes	2 %	2.5 %
Ketones	0 %	0.1 %
Aromatics	44 %	33.0 %

Selected literature

- Caplain, Isabelle, et al. "Emissions of Unregulated Pollutants from European Gasoline and Diesel Passenger Cars." Atmospheric Environment, 2006, doi:10.1016/j.atmosenv.2005.12.049.

- Cao, Xinyue, et al. "On-Road Emission Characteristics of VOCs from Light-Duty Gasoline Vehicles in Beijing, China." Atmospheric Environment, 2016, doi:10.1016/j.atmosenv.2015.06.019.

- May, Andrew A., et al. "Gas- and Particle-Phase Primary Emissions from in-Use, on-Road Gasoline and Diesel Vehicles." Atmospheric Environment, 2014, doi:10.1016/j.atmosenv.2014.01.046.

- Cazier, Fabrice, et al. Determination of VOC Components in the Exhaust of Light Vehicles Fuelled with Different Biofuels. 2010, pp. 260–66, https://hal.archives-ouvertes.fr/hal-00978548/.

- Hong-li, Wang, et al. "Volatile Organic Compounds (VOCs) Source Profiles of on-Road Vehicle Emissions in China." Science of the Total Environment, 2017, doi:10.1016/j.scitotenv.2017.07.001.

- Cai, H., and S. D. Xie. "Tempo-Spatial Variation of Emission Inventories of Speciated Volatile Organic Compounds from on-Road Vehicles in China." Atmospheric Chemistry and Physics, 2009, doi:10.5194/acp-9-6983-2009.

- Liu, Ying, et al. "Source Profiles of Volatile Organic Compounds (VOCs) Measured in China: Part I." Atmospheric Environment, 2008, doi:10.1016/j.atmosenv.2008.01.070.

- Dröge, Rianne, et al. Emissions of Two-Wheeled Vehicles. 2011, pp. 1–75, TNO Report, Delft, the Netherlands.

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Planned updates for next year

- Review of emission degradation functions

- Inclusion of electrified vehicles (diesel hybrids, plug-in hybrids, battery electric vehicles)

- Revision of PM characteristics (particle number and surface area) as a result of H2020 projects

- Review of Euro 6d emission factors in light of new RDE measurements

- Revision of non-exhaust emissions from tyre wear

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Thank you for your attention!