Guidebook updates

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





New elements in 2021

- Introduction of Solid Particle Number (SPN23) emission factors
- Revision of Particle Mass (exhaust only) emission factors
- Revision of emission factors for mini-cars and ATVs
- Revision of emission factors for shipping (1.A.3.d)



Introduction of Solid Particle Number (SPN23) emission factors and revision of exhaust PM emission factors





Data Collection







- Vehicles sub-categories based on type, fuel, Euro Standard
- Driving cycles (lab and on-road) divided in cold or hot start
- Calculation of average emission factors and level of confidence
- Estimations, where needed
- Solid Particle Number (SPN23)
 - All vehicle types and Euro standards
- Particle Mass (PM Exhaust)
 - Revision of the most recent Euro standards based on latest research data



Number of measurements considered

SPN23			Cold			Hot			Regeneration		
			Lab	On-road	Total	Lab	On-road	Total	Lab	On-road	Total
Diesel	Euro 5	DPF	4	2	6	3	-	3	1		1
Diesel	Euro 6	DPF	85	33	118	35	3	38	8	4	12
Petrol	Euro 6	GDI	29	21	50	19	2	21			
Petrol	Euro 6	GDI+GPF	11	11	22	5	-	5			
Petrol	Euro 6	PFI	14	18	32	5	1	6			
CNG	Euro 6		31	3	34	5	1	6			

Number of passenger cars SPN23 measurements

Number of passenger cars PM measurements

PM			Cold			Hot		
			Lab	On-road	Total	Lab	On-road	Total
Diesel	Euro 5	DPF	8	-	8			
Diesel	Euro 6	DPF	7	3	10			
Petrol	Euro 5	GDI	10	-	10	5	-	5
Petrol	Euro 6	GDI	3	-	3	3		3

Number of Heavy-Duty Vehicles SPN23 measurements

SPN23	[#/kWh]		Lab	On-road	Total
HDV	Diesel	HDV Rigid <12 t	4	2	6
HDV	Diesel	HDV Articulated 22-27 t	3	3	6
Urban Bus	Diesel	Urban Bus Diesel	1		1
Urban Bus	CNG	Urban Bus CNG	1		1



Passenger Cars – SPN23

SPN23 [#/km]	Euro Standard	Urban	Rural	Highway
Diesel	Euro 1	3,97E+14	2,52E+14	4,70E+14
Diesel	Euro 2	2,12E+14	2,05E+14	4,35E+14
Diesel	Euro 3	1,64E+14	1,73E+14	2,82E+14
Diesel	Euro 4	7,48E+13	5,52E+13	9,00E+13

SPN23 [#/km]	Euro Standard	Technology	Urban	Rural	Highway
Petrol	Euro 1	PFI	8,76E+12	3,11E+12	1,81E+13
Petrol	Euro 2	PFI	6,16E+12	2,67E+12	1,18E+13
Petrol	Euro 3	PFI	3,07E+12	2,23E+12	5,60E+12
Petrol	Euro 4	PFI	9,00E+11	7,90E+11	8,40E+11
Petrol	Euro 4	GDI	9,50E+12	7,60E+12	6,06E+13

SPN23 [#/km]	Euro Standard	Technology	Cold	Hot
Diesel	Euro 5	DPF	2,09E+11	8,73E+10
Diesel	Euro 6	DPF	1,72E+11	4,82E+10
Petrol	Euro 5	GDI	1,85E+12	7,65E+11
Petrol	Euro 5	PFI	1,39E+12	6,10E+11
Petrol	Euro 6	GDI	1,97E+12	8,12E+11
Petrol	Euro 6	GDI+GPF	5,55E+11	1,30E+11
Petrol	Euro 6	PFI	1,47E+12	6,48E+11





SPN23 [#/kWh]	Euro Standard	Urban	Rural	Highway
Heavy Duty Vehicle	Euro I	7,34E+14	3,18E+14	3,28E+14
Heavy Duty Vehicle	Euro II	5,13E+14	2,21E+14	2,30E+14
Heavy Duty Vehicle	Euro III	5,13E+14	2,21E+14	2,30E+14
Heavy Duty Vehicle	Euro IV	1,08E+14	5,54E+13	6,18E+13
Heavy Duty Vehicle	Euro V	1,08E+14	5,54E+13	6,18E+13
Heavy Duty Vehicle	Euro VI	1,79E+11	6,09E+10	4,75E+10





SPN23 [#/km]	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5
Mopeds 2s	1,00E+13	8,00E+12	7,00E+12	4,00E+12	4,00E+12
Mopeds 4s	1,00E+13	2,00E+12	5,00E+11	5,00E+11	5,00E+11
Motorcycles	3,00E+12	3,00E+12	1,07E+12	8,54E+11	8,54E+11
Quads	5,80E+12	2,90E+12	2,90E+12	1,00E+12	1,00E+12
Minicars	8,00E+13	4,00E+13	4,00E+13	2,00E+13	2,00E+13





PM exhaust emission factors revision





Reduced emission factors for

- Euro 5 & 6 diesel passenger cars
- Euro 6 petrol passenger cars



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Revision of emission factors for mini-cars and ATVs



Data source

- Tests performed in the framework of the "Effect study of the environmental step Euro 5 for L-category vehicles" (Ntziachristos et al., 2017)
- Sample: two minicars (L6e-B) and four ATVs (L7e-B) were tested at JRC

category	category name	engine capacity class [cc]	rated power [kW]	engine combustion type*	# of cylinders	Maximum design speed [km/h]	Transmission	Euro class	Fuel delivery system	Secondary Air System (SAS)	catalyst**	reference mass class [kg]	year	mileage [km]***	WMTC ****	ECE R47 ****	ECE R40 ****	WOT ****	SRC-LeCV ****	AMA ****
L6e-BP	light quadri-mobile	480	4	D-4S	2	45	CVT	Euro 2	injection	No	2w	470	2015	0	9	6		3		
L6e-BU	light quadri-mobile	400	4	D-4S	2	45	CVT	Euro 2	injection	No	n.a.	480	2014	988	4	2		1	1	2
L7e-B1	all terrain quad	980	15	G-4S	2	65	CVT	Euro 2	injection	No	3w	470	2016	538	2		2	1		
L7e-B1	all terrain quad	570	11	G-4S	1	70	CVT	Euro 2	injection	No	2w	450	2015	900	11		5	3	4	1
L7e-B1	all terrain quad	440	17	G-4S	1	67	CVT	Euro 2	injection	No	3w	370	2016	17	6		2	1		
L7e-B2	side-by-side buggy	700	15	G-4S	2	78	CVT	Euro 2	injection	No	2w	570	2016	638	6		5	4	3	2

* G = gasoline; D = Diesel; E=Electric; 2S = 2-stroke; 4S = 4-stroke

** 2w = 2-way catalyst; 3W = 3-way catalyst

*** mileage at vehicle take-in, before any applied degreening

**** number of repetitions

n.a. = not applicable

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Methodology for EFs development

- Second-by-second modal data used
- Pollutants: CO, HC, NOx and PM and FC
- Driving cycles:
 - 'Revised' Worldwide harmonized Motorcycle Test Cycle (WMTC Stage 3) class 2-1
 - The ECE R47 for minicars and the ECE R40 for ATVs
 - Wide-Open Throttle (WOT)
 - Standard Road Cycle for L-Category Vehicles (SRC-LeCV)
 - USA EPA Approved Mileage Accumulation (AMA)
- Each driving cycle split to cold/hot parts



Example graph: average emission levels of the ECE R47 driving cycle second-by-second data for minicars, for CO. Error bars indicate min and max values within the test vehicles (after averaging in each vehicle's cycle runs). Parts 1-2: cold start, parts 3-8: hot.



		Average Speed [km/h]	CO [g/km]	HC [g/km]	HC NOx [g/km] [g/km]		PM [mg/km]	
			Minicars					
urban	cold start	24	0.31	0.14	0.54	2.97	68.67	
urbari	hot start	34	0.53	0.86	0.60	3.68	37.00	
			ATVs					Share*
urban	cold start	21	18.19	1.06	0.49	22.39	5.77	17 000/
urball	hot start	28	1.89	0.16	0.25	8.15	1.42	47.80%
rural	cold start	-	-	-	-	-	-	52 20%
	hot start	53	11.47	0.29	0.53	7.13	5.72	52.20%

* Based on COPERT data





Mini-cars and ATVs EFs per Euro standard

Category	Euro Standard	CO [g/km]	VOC [g/km]	NOx [g/km]	EC [MJ/km]	PM Exhaust [g/km]
Quad & ATVs	Euro 1	11.81	0.884	0.40	2.50	0.007
Quad & ATVs	Euro 2	6.89	0.228	0.40	2.50	0.004
Quad & ATVs	Euro 3	6.89	0.228	0.40	2.50	0.004
Quad & ATVs	Euro 4	1.59	0.228	0.25	2.43	0.004
Quad & ATVs	Euro 5	0.89	0.100	0.08	2.43	0.004
Mini-car	Euro 1	0.53	0.860	0.60	1.32	0.037
Mini-car	Euro 2	0.53	0.860	0.60	1.32	0.037
Mini-car	Euro 3	0.53	0.860	0.60	1.32	0.037
Mini-car	Euro 4	0.53	0.100	0.51	1.19	0.020
Mini-car	Euro 5		Not e	xpected to ente	r the market	

- Assumptions for the development of EFs for each technology
 - Euro 2: developed directly from tests
 - Euro 3: the same EFs as Euro 2, considering that the respective emission limits have not changed
 - Euro 4 and Euro 5: based on engineering judgment, also considering the respective emission limits
 - Euro 5 mini-cars are not expected to be introduced in the market



Energy consumption and emission factors for marine diesel engines



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New Methodology

EFs development process



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Data collection

Database construction with emission rates from literature (papers, studies, reports, inventories)

Database structure

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Content per pollutant and engine utility



European Environment Agency European Topic Centre on Air pollution, transport, noise and industrial pollution



157 literature sources

Processing





Processing Example

Base EF (Average values of measurements)

Pollutant	Engine type		
	Slow speed	Medium speed	High speed
NO _x (g/kWh)	14,4	12,4	11,7
CO (g/kWh)	0,714	0,974	1,10
HC (g/kWh)	0,358	0,405	0,662
SFOC (MJ/kWh)	8,48	8,42	9,74

Load Correction (Normalized emission rates' load dependency)



EFs development at each engine load for:

- pollutants (NOx, CO, PM, HC, etc..) and SFOC
- engine types (slow, medium, high speed)
- fuels (BFO, MDO/MGO, LNG)

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Source: SCIPPER 2021

Tiers 1,2,3 updates

• Tier 3

- Calculation of new EFs for engine loads of 80% & 20% (main engines) and 30% & 50% for auxiliary engines.
- Consideration for main engines → 80% engine load corresponds to cruising and 20% to maneuvering/at berth.
 For auxiliary engines → 30% to cruising and 50% to maneuvering/berth
- Tier 3 EFs update per fuel, engine type and operating mode

• Tier 2

- Calculation of new EFs for an average entire trip, using engine loads sequence and frequency weighting factors of the E2 test cycle
- Tier 2 EFs update per fuel and engine type
- Tier 1
 - Use of Tier 2 EFs adjusting them for a typical fleet consideration (50% slow, 50% medium speed)
 - Tier 1 EFs update per fuel type



Pollutants' specific treatments

• NOx

 For NOx emissions, a further distinction of EFs per engine technology standard (NOx engine Tiers) is made (a relevant table has been inserted)

• PM

- PM is calculated on the basis of the sum of its speciation (OM, EC, Ash, hydrated sulphates (SO₄ + 6,5H₂O))
- EC and BC are assumed equivalent
- BC fraction is replaced by BC estimation from literature
- In Tiers 1,2,3, TSP and PM₁₀ are equal and PM_{2,5} is estimated as a fraction of PM₁₀ (in Tiers 1&2)

Note: Default fuels used

- All calculations per fuel type are performed for average fuel properties, as derived from literature



Emission controls

Correction of EFs based on the application of emission control technologies

$$RevEF_{i,m,j} = \sum_{c} (EF_{i,m,j} x (1 - C_c) x f_c)$$

where:

RevEF_{i,m,j} = revised fuel consumption-specific emission factor of pollutant i, fuel type m [kg/tonne] and engine type j; EF_{i,m} = fuel consumption-specific emission factor of pollutant I, fuel type m [kg/tonne] and engine type C_c = correction factor for emission control technologies. f_c = distribution of emission control technology on the considered fleet.

Table with correction factors per pollutant for various emission control technologies

- Wet Scrubbers
- SCR
- DOC
- DPF
- Combination from technologies

For Tiers 2&3

European Environment Agency European Topic Centre on Air pollution transport, noise and industrial pollution



Source: EMERGE 2020

Planned updates for next year

- Review of emission degradation functions
- Review of cold start emissions methodology
- Review of vehicle data related to evaporative emissions
- Revision of non-exhaust emissions from tyre wear (partly done in 2020)



Thank you for your attention!



