

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)

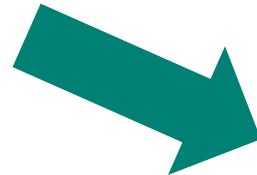


Introduction of Solid Particle Number (SPN23) emission factors and revision of exhaust PM emission factors

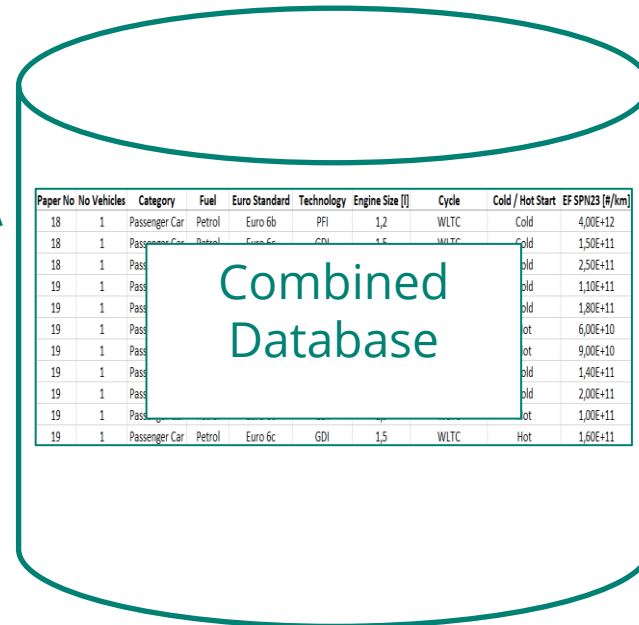
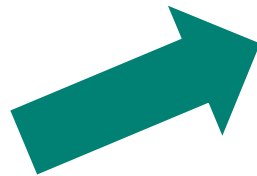


Data Collection

Laboratory
Measurements



Literature
Review



Passenger cars

Light commercial
vehicles

Heavy duty
vehicles

L-category
vehicles



Methodology

- 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

Number of passenger cars SPN23 measurements

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 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



Heavy Duty Vehicles – SPN23

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

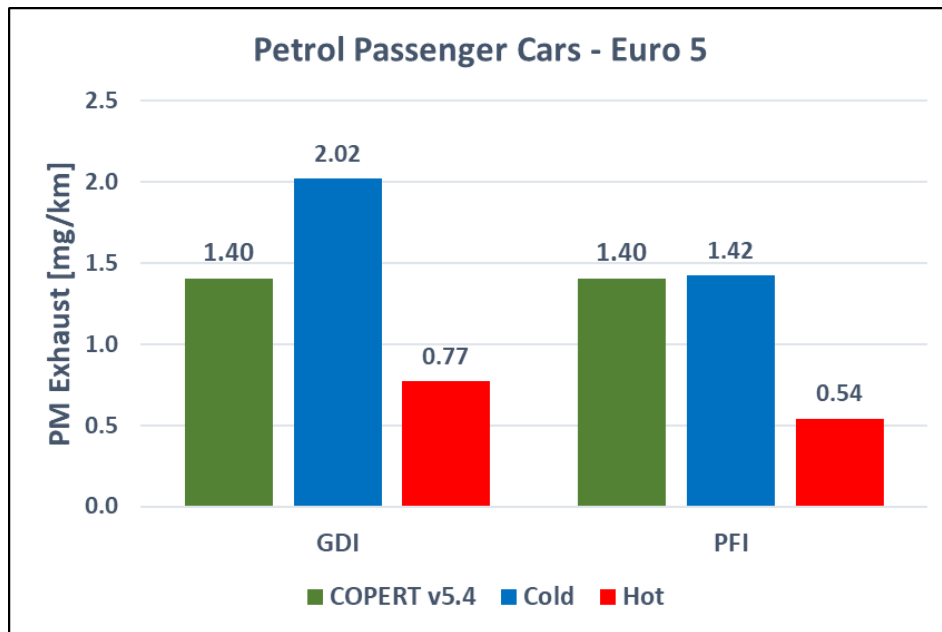
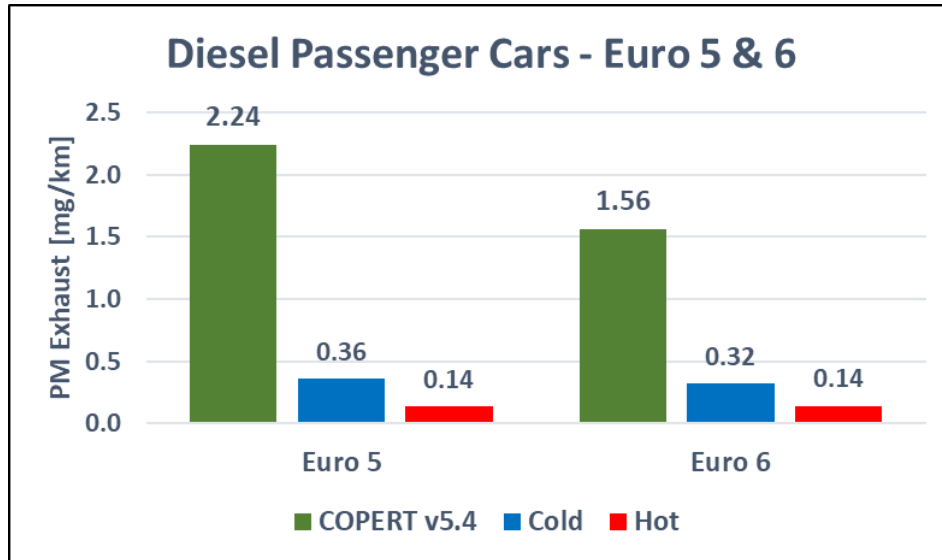


L-Category vehicles – SPN23

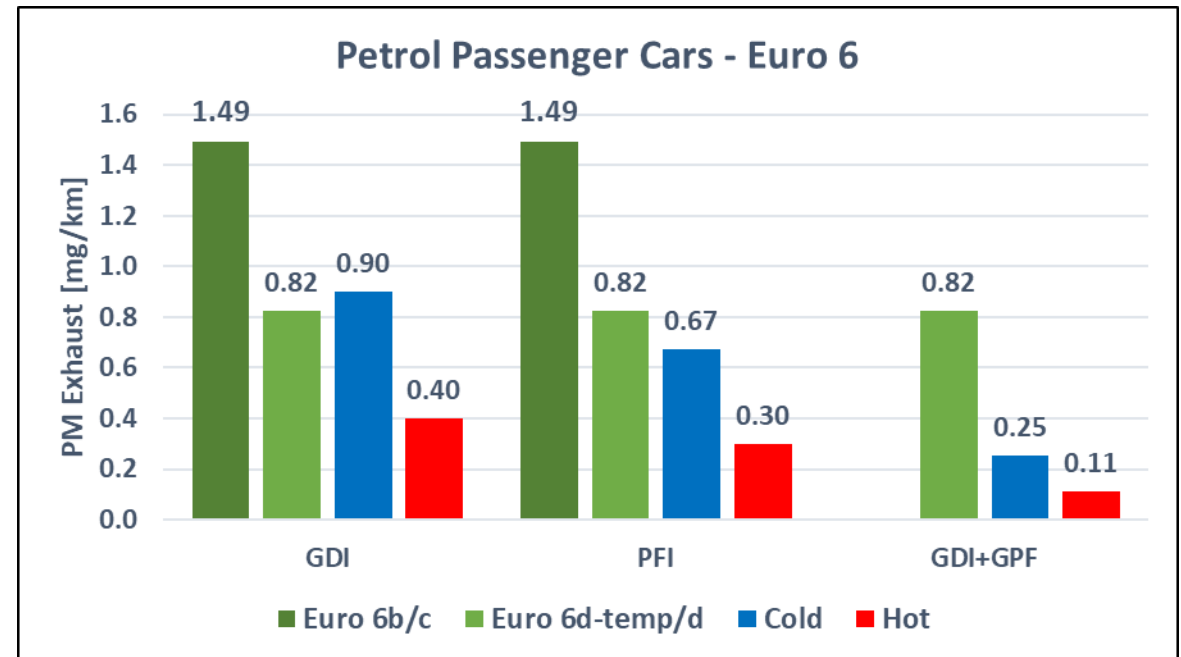
SPN23 [#/km]	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5
Mopeds 2s	1,00E+13	8,00E+12	7,00E+12	4,00E+12	4,00E+12
Mopeds 4s	1,00E+13	2,00E+12	5,00E+11	5,00E+11	5,00E+11
Motorcycles	3,00E+12	3,00E+12	1,07E+12	8,54E+11	8,54E+11
Quads	5,80E+12	2,90E+12	2,90E+12	1,00E+12	1,00E+12
Minicars	8,00E+13	4,00E+13	4,00E+13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



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

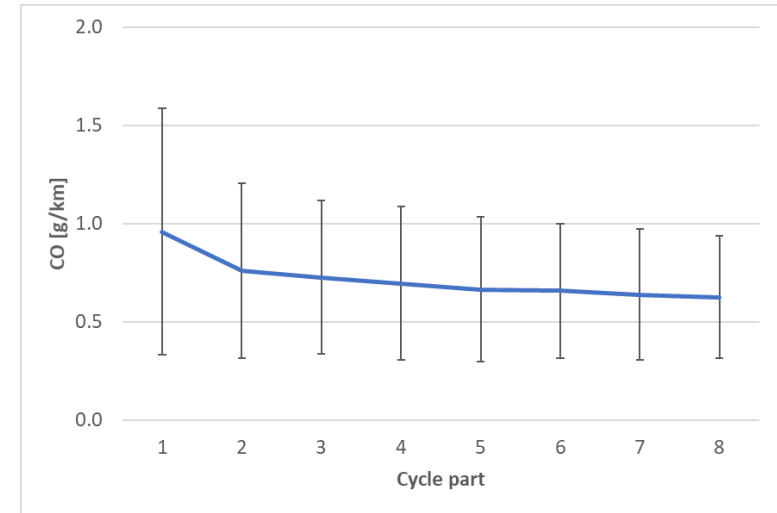
**** number of repetitions

n.a. = not applicable



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.



Test results for Euro 2 vehicles

		Average Speed [km/h]	CO [g/km]	HC [g/km]	NOx [g/km]	FC [l/100km]	PM [mg/km]	
Minicars								
urban	cold start	24	0.31	0.14	0.54	2.97	68.67	
	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	47.80%
	hot start	28	1.89	0.16	0.25	8.15	1.42	
rural	cold start	-	-	-	-	-	-	52.20%
	hot start	53	11.47	0.29	0.53	7.13	5.72	

* 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 expected to enter 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

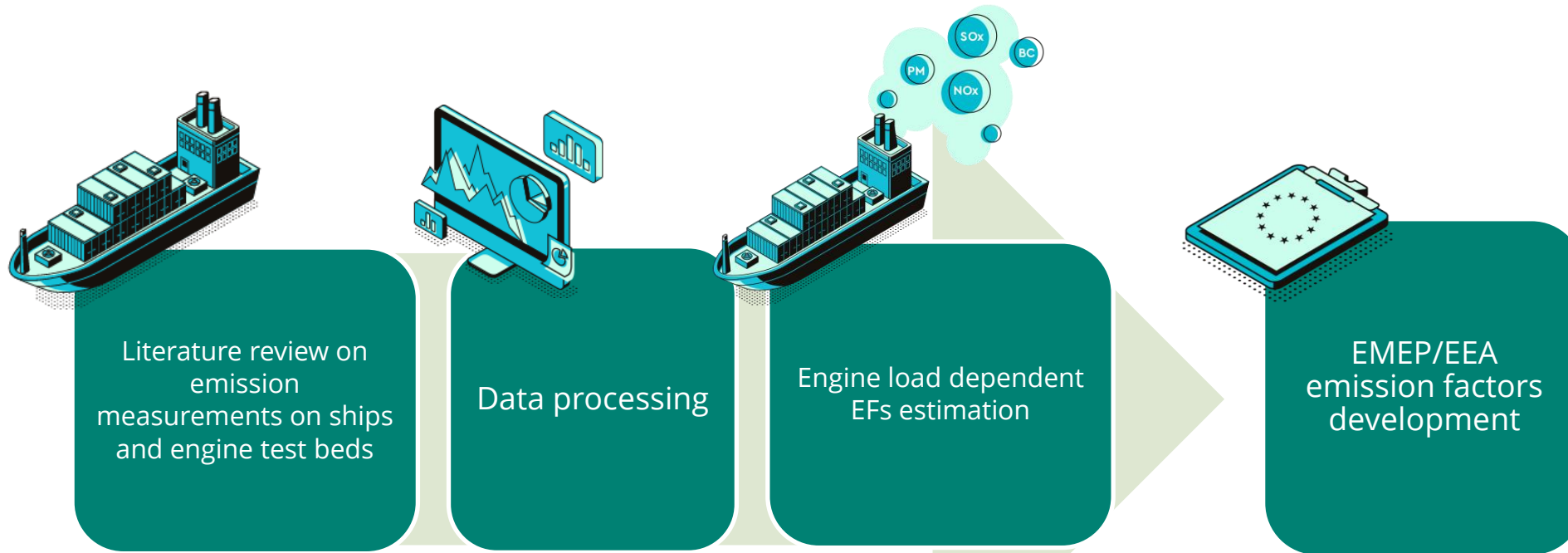


Energy consumption and emission factors for marine diesel engines



New Methodology

EFs development process



Source: SCIPPER 2021



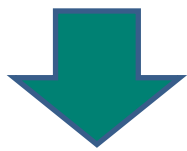
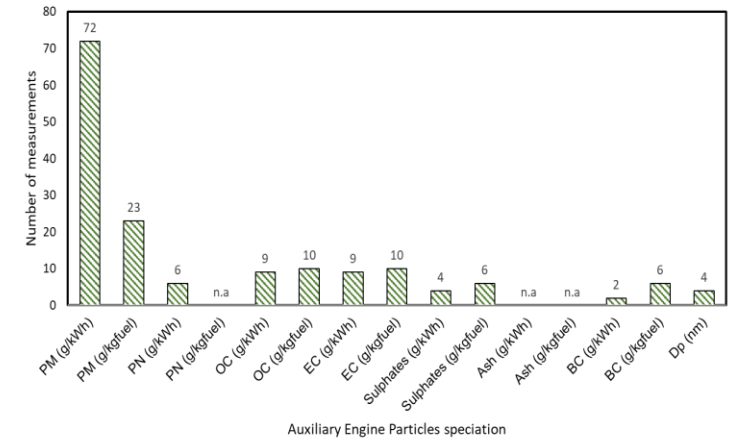
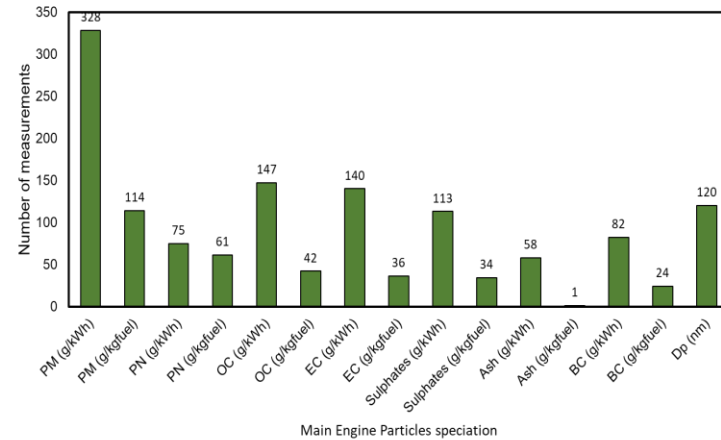
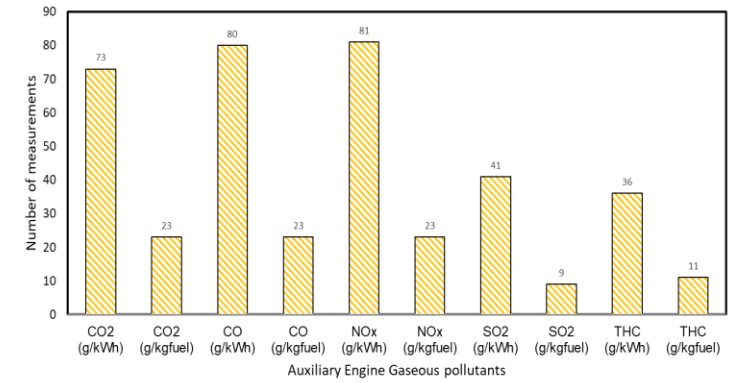
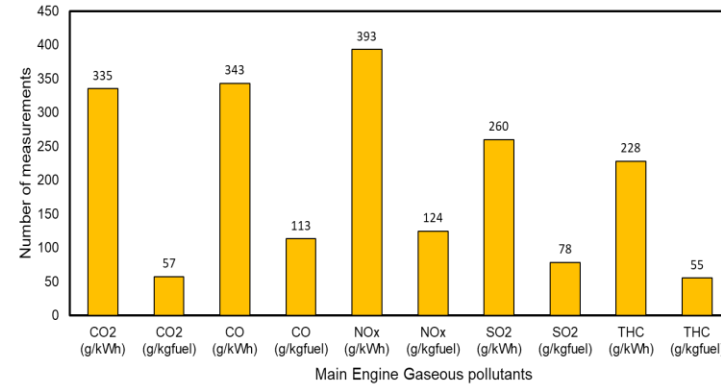
Data collection

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

Database structure

Paper No.	A/A	Test Method	Vessel Type	Vessel info				Main				Auxiliary			
				IMO No.	DWT (tonnes)	GT (tonnes)	Year Built	Engine name	Stroke	Speed (rpm)	MCR (kW)	Engine name	Stroke	Speed (rpm)	MCR (kW)
1	1	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	nominal 127	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
1	2	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	nominal 127	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
1	2	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	nominal 127	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
1	2	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	115	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
1	2	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	102.5	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
1	2	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	90	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
1	2	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	68	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
1	3	OnBoard	Handy size Bulk Carrier		45308	31113	2012	MAN B&W 6550ME CS	2 stroke diesel	nominal 127	7948	MAN B&W 6L16/24	4 stroke diesel	1200	660
2	4	OnBoard	Tugboat		360	1998			4 stroke diesel	750	2648				
2	4	OnBoard	Tugboat		360	1998			4 stroke diesel	750	2648				
2	4	OnBoard	Tugboat		360	1998			4 stroke diesel	750	2648				
2	5	OnBoard	Container		2289	2011			4 stroke diesel	1200	880				
2	5	OnBoard	Container		2289	2011			4 stroke diesel	1200	880				
2	5	OnBoard	Container		2289	2011			4 stroke diesel	1200	880				
2	6	OnBoard	Container		2612	2006			4 stroke diesel	1500	900				
2	6	OnBoard	Container		2612	2006			4 stroke diesel	1500	900				
2	7	OnBoard	Container		3221	2012			4 stroke diesel	1500	900				
2	7	OnBoard	Container		3221	2012			4 stroke diesel	1500	900				
2	7	OnBoard	Container		3221	2012			4 stroke diesel	1500	900				
2	8	OnBoard	Container		3748	2010			4 stroke diesel	750	1620				
2	8	OnBoard	Container		3748	2010			4 stroke diesel	750	1620				
2	8	OnBoard	Container		3748	2010			4 stroke diesel	750	1620				
2	9	OnBoard	Roro ship		6028	2005			4 stroke diesel	750	1830				
2	9	OnBoard	Roro ship		6028	2005			4 stroke diesel	750	1830				
2	9	OnBoard	Roro ship		6028	2005			4 stroke diesel	750	1830				
2	10	OnBoard	Passenger Liner		4044	2003			4 stroke diesel	900	1560				
2	10	OnBoard	Passenger Liner		4044	2003			4 stroke diesel	900	1560				
2	10	OnBoard	Passenger Liner		4044	2003			4 stroke diesel	900	1560				

Content per pollutant and engine utility

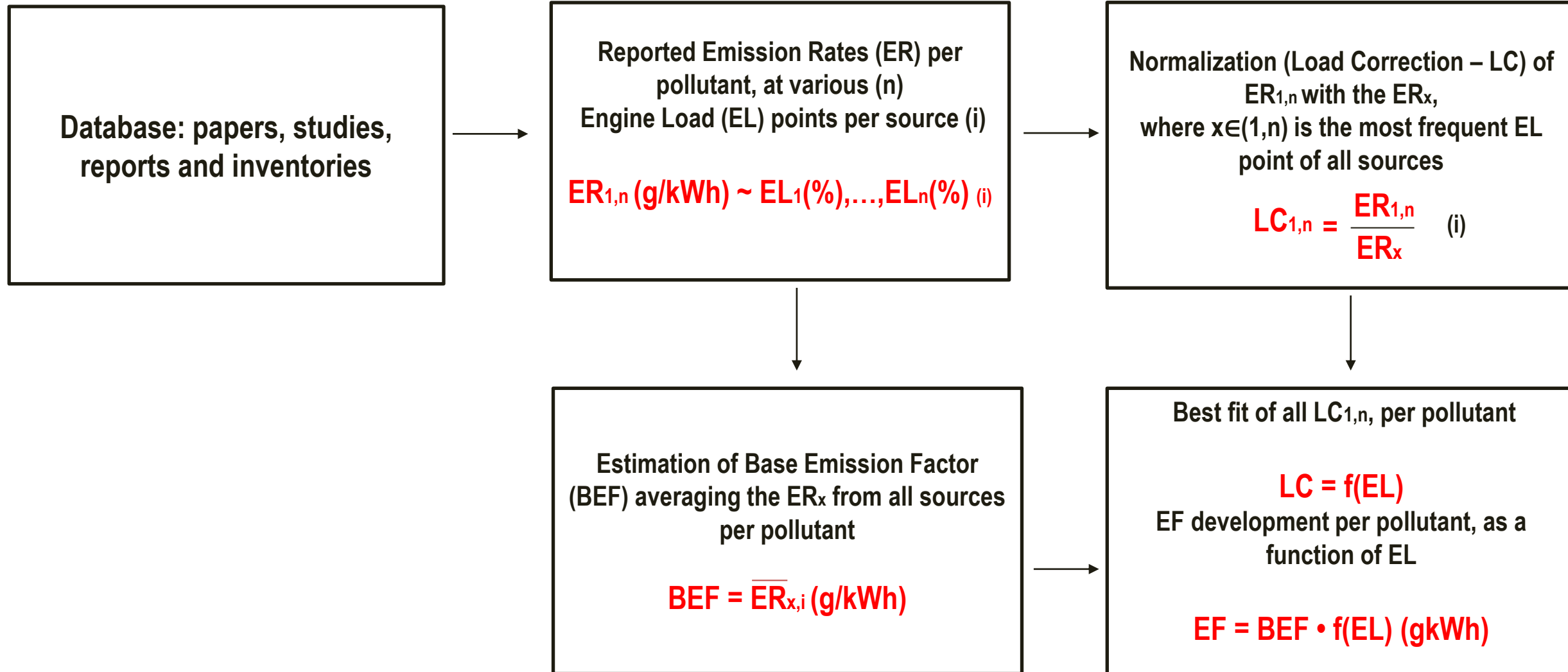


157 literature sources

Source: SCIPPER 2021



Processing



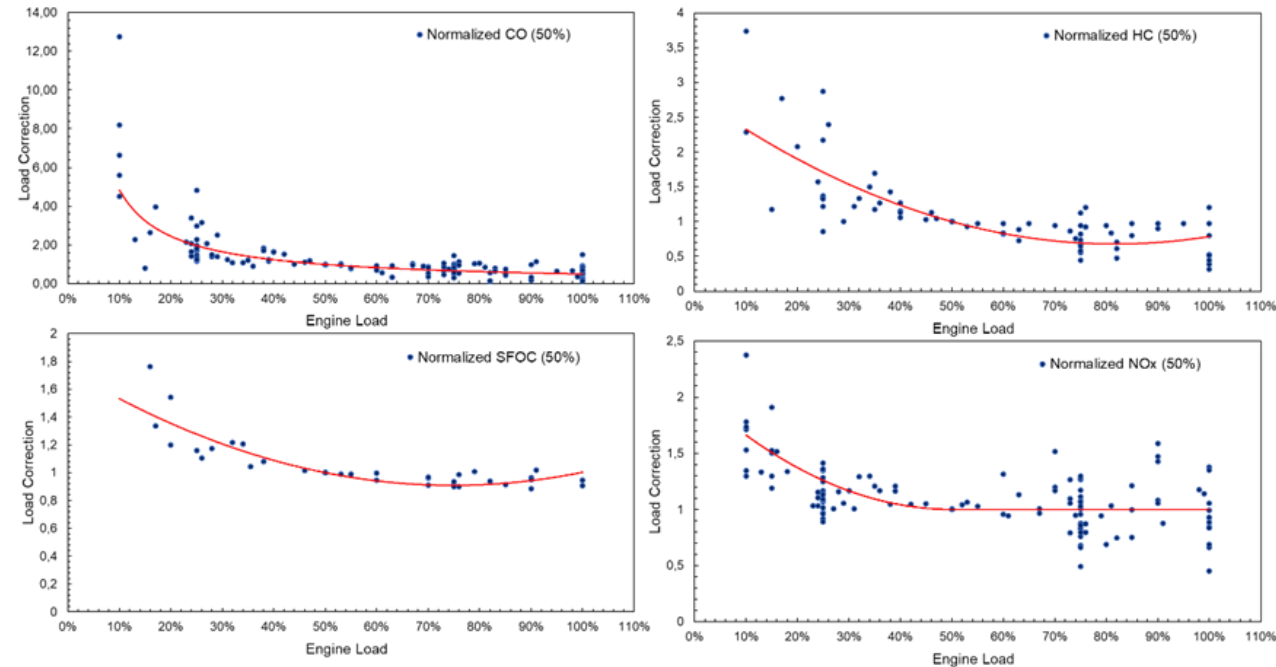
Processing Example

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



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

- NO_x

- For NO_x emissions, a further distinction of EFs per engine technology standard (NO_x 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

$$RevEF_{i,m,j} = \sum_c (EF_{i,m,j} \times (1 - C_c) \times f_c)$$

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.

For Tiers 2&3

Table with correction factors per pollutant for various emission control technologies

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



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!

