

1.A.3.d - Navigation

Short description

Category 1.A.3.d - Navigation includes emissions from national and international inland and maritime navigation.

NFR-Code	Name of Category	Method	AD	EF	Key Category Analysis
1.A.3.d	Navigation	see sub-category details			
consisting of / including source categories					
1.A.3.d i (ii)	International Inland Waterways	Germany does not report emissions from this sub-category.			
1.A.3.d ii	National Navigation (Shipping)	see sub-category details			
1.A.3.d i (i)	International Maritime Navigation	see sub-category details			

Methodology

Activity Data

Primary fuel deliveries data for the entire navigation sector (maritime and inland waterways) is included in lines 6 ('International Maritime Bunkers') and 64 ('Coastal and Inland Navigation') of the National Energy Balance (NEB) (AGEB, 2022) ¹⁾. (For comparison, official mineral-oil data of the Federal Office of Economics and Export Control (BAFA, 2022) ²⁾ are applied, too.)

Data on the consumption of *biodiesel* is provided in NEB line 64 from 2004 onward. However, as this data appears to be rather inconsistent, the consumption of biofuels is calculated within TREMOD via the official annual blending rates.

Table 1: Primary fuel deliveries as listed in the National Energy Balance, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
NEB line 6 - Maritime Bunkers ('Hochseebunkierungen')																
Diesel / Light heating oil	23,336	20,426	21,542	18,636	22,483	21,046	18,617	18,333	20,898	43,376	42,606	36,872	31,406	30,214	22,789	30,312
Heavy fuel oil	80,230	64,382	69,578	85,370	93,063	92,649	87,595	77,754	73,729	57,900	74,844	58,788	39,570	26,959	32,621	28,423
NEB line 64 - Coastal and Inland Navigation ('Küsten- und Binnenschifffahrt')																
Diesel oil	27,710	23,562	11,864	12,831	11,182	12,050	11,322	11,635	12,112	13,321	11,131	10,150	10,619	11,259	10,076	10,481
TOTAL	131,276	108,370	102,984	116,837	126,728	125,745	117,534	107,722	106,739	114,597	128,581	105,81	81,595	68,432	65,487	69,216

source: National Energy Balances ³⁾

As the statistical allocation of fuels delivered to the navigation (shipping) sector follows tax aspects, NEB line 6 ('International Maritime Bunkers') includes all fuel deliveries to IMO-registered ship involved in both national and international maritime activities. On the other hand, NEB line 64 ('Coastal and Inland Navigation') includes all fuel deliveries to ship involved in inland and non-IMO maritime navigation.

Table 2: Allocation of for subsector-specific fuel deliveries data in the NEB

NEB line	including fuel deliveries to navigation sub-sectors...
6 - 'International Maritime Bunkers'	...international maritime navigation / national maritime navigation (IMO) / national fishing (IMO) / military navigation (IMO)
64 - 'Coastal and Inland Navigation'	...national inland navigation / national maritime navigation (non-IMO) / national fishing (non-IMO) / military navigation (non-IMO)

Therefore, the amounts of fuels listed in NEB lines 6 and 64 are broken down on several sub-sectors.

Regarding all national maritime activities, taking place in National Maritime Navigation, national fishing, and military navigation, a country-specific approach allows for estimating tier3 fuel consumption data based on ship movement information (AIS signal) for IMO- and non-IMO ships.

In contrast to this bottom-up approach, fuel consumption in both *international maritime navigation* and *national inland navigation* are calculated as tier1 estimates. The following equations and charts try to illustrate the way of deducing these tier1 activity data:

Estimating the tier1 activity data for International maritime navigation:

$AD_{1.A.3.d\ i} = PAD_{NEB\ line\ 6} - AD_{1.A.3.d\ ii\ (a) - IMO} - AD_{1.A.4.c\ iii - IMO} - AD_{1.A.5.b\ iii - IMO}$	with * $AD_{1.A.3.d\ i}$ - tier1 activity data for International maritime navigation * $PAD_{NEB\ line\ 6}$ - primary over-all fuel deliveries data from NEB line 6 - 'International Maritime Bunkers' * $AD_{1.A.3.d\ ii\ (a) - IMO}$ - tier3 activity data for IMO-registered ships involved in national maritime navigation * $AD_{1.A.4.c\ iii - IMO}$ - tier3 activity data for IMO-registered ships involved in national fishing * $AD_{1.A.5.b\ iii - IMO}$ - tier3 activity data for IMO-registered ships involved in military navigation
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Estimating the tier1 activity data for National inland navigation:

$AD_{1.A.3.d\ ii\ (b)} = PAD_{NEB\ line\ 64} - AD_{1.A.3.d\ ii\ (a) - non-IMO} - AD_{1.A.4.c\ iii - non-IMO} - AD_{1.A.5.b\ iii - non-IMO}$	with * $AD_{1.A.3.d\ ii\ (b)}$ - tier1 activity data for National inland navigation * $PAD_{NEB\ line\ 64}$ - primary over-all fuel deliveries data from NEB line 64 - 'Coastal and Inland Navigation' * $AD_{1.A.3.d\ ii\ (a) - non-IMO}$ - tier3 activity data for non-IMO ships involved in national maritime navigation * $AD_{1.A.4.c\ iii - non-IMO}$ - tier3 activity data for for non-IMO ships involved in national fishing * $AD_{1.A.5.b\ iii - non-IMO}$ - tier3 activity data for for non-IMO ships involved in military navigation
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Table 3: Resulting breakdown of primary fuel deliveries onto the different navigation sub-sectors, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
TOTAL	131,276	108,370	102,984	116,837	126,728	125,745	117,534	107,722	106,739	114,597	128,581	105,81	81,595	68,432	65,487	69,216
1.A.3.d i - International maritime navigation																
Diesel oil / Light heating oil	13,162	13,096	13,709	11,820	16,417	15,020	12,181	11,875	13,801	33,958	32,832	27,463	21,473	20,231	13,896	21,454
Heavy fuel oil	76,942	62,066	67,080	83,224	91,169	90,779	85,586	75,559	71,598	57,792	74,807	58,707	39,308	26,565	32,253	28,031
1.A.3.d ii (a) - National maritime navigation																
Diesel oil / Light heating oil	9,484	6,828	7,367	6,399	5,690	5,669	6,089	6,133	6,766	8,980	9,335	8,960	9,445	9,497	8,339	8,475
Heavy fuel oil	3,103	2,186	2,382	2,054	1,810	1,790	1,932	2,134	2,057	108,0	37,0	81,1	262	394	368	392
									17.3	22.0	64.4	58.8	197	153	276	293
1.A.3.d ii (b) - National inland navigation																
Diesel oil	27,716	23,562	11,864	12,851	11,182	12,050	11,322	11,635	12,112	13,321	11,131	10,150	10,619	11,259	10,076	10,481
1.A.4.c iii - Fishing																
Diesel oil / Light heating oil	305	240	238	226	227	213	209	214	227	284	298	293	356	322	359	265
Heavy fuel oil	33.3	26.0	26.0	24.4	24.5	23.0	22.6	16.8	13.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.A.5.b iii - Military navigation																
Diesel oil / Light heating oil	380	263	228	171	150	144	138	111	104	154	141	156	133	164	195	118
Heavy fuel oil	152	104	90.4	67.4	59.0	56.5	54.0	43.9	60.5	0	0	0	0	0	0	0

Emission factors

Annual country-specific emission factors have been developed within the underlying models maintained at the ifeu Institute for Energy and Environmental Research (Knörr et al. (2022a): TREMOD) ⁴⁾ and the Federal Maritime and Hydrographic Agency (Deichnik (2022): BSH model) ⁵⁾.

For information on these country-specific emission factors, please refer to the sub-chapters linked above.

Impact of fuel-sulphur regulation on sulphur dioxide

Table 4: Development of fuel-sulfur limits for maritime fuels in SECAs ⁶⁾, in [% m/m]

mid-2006 to mid-2010	1.50	
mid-2010 to 2015	1.00	LSFO ²
as of 2015	0.10	ULSFO ³

¹⁾ SECA = Sulphur Emission Control Area (Wikipedia, 2023) ⁷⁾ ²⁾ Low-sulphur Fuel Oil ³⁾ Ultra-low-sulphur Fuel Oil

These fuel-sulfur limits listed are used for the derivation of emission factors especially for heavy fuel oil used in the German inventory. Here, until 2006, a global average of 2.70 % m/m is applied.

Table 5: Development of global fuel-sulfur limits for maritime fuels, in [% m/m]

until 2012	4.50
2012 to 2020	3.50
as of 2020	0.50

Heavy metals and POPs

For heavy metal and POP emissions, tier1 EF have been derived from the EMEP/EEA Guidebook 2019 mainly ⁸⁾.



For information on the **emission factors for heavy-metal and POP exhaust emissions**, please refer to Appendix 2.3 - Heavy Metal (HM) exhaust emissions from mobile sources and Appendix 2.4 - Persistent Organic Pollutant (POP) exhaust emissions from mobile sources.

Table 4 shows the tier1 emission factors for exhaust emissions of **heavy-metals** and **POPs** as applied to all navigation sub-categories in 1.A.3.d as well as NFRs 1.A.4.c iii and 1.A.5.b iii. The listed values have been derived from default values provided in the EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA, 2019) ⁹⁾ and (Rentz et al., 2008) ¹⁰⁾.

Here, as the guidebook does not provide source-specific values for **PAHs**, respective values provided for diesel in railways and heavy duty road vehicles have been applied as a gap-filling proxy.

Table 6: Tier1 emission factors for heavy-metal and POP exhaust emissions

	Pb	Cd	Hg	As	Cr	Cu	Ni	Se	Zn	B[a]P	B[b]F	B[k]F	I[...]p	PAH 1-4	PCBs	HCB	PCDD/F
	[g/T]									[mg/T]							
Diesel oil	3.03 ₂	0.233 ₂	0.698 ₂	0.93 ₂	1.16 ₂	20.5 ₂	23.3 ₂	2.33 ₂	27.9 ₂	698 ⁵	1,164 ⁵	801 ⁶	184 ⁶	2,847 ⁴	0.885 ₂	1.86 ₂	93.0 ⁷
Heavy fuel oil	4.46 ₃	0.496 ₃	0.496 ₃	16.9 ₃	17.8 ₃	31.0 ₃	793 ₃	5.20 ₃	29.7 ₃	741 ⁵	1,235 ⁵	849 ⁶	195 ⁶	3,020 ⁴	14.1 ₃	3.46 ₃	98.7 ⁷

²⁾ tier1 defaults from ¹¹⁾, Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Table 3-2

³⁾ tier1 defaults from ¹²⁾, Chapter: 1.A.3.d.i, 1.A.3.d.ii, 1.A.4.c.iii Navigation: Table 3-1

⁴⁾ sum of tier1 default values applied for B[a]P, B[b]F, B[k]F, and I[1,2,3-c,d]P

⁵⁾ tier1 defaults from ¹³⁾, Chapter: 1.A.3.c Railways: Diesel, Table 3-1

⁶ tier1 defaults from ¹⁴⁾, Chapter: 1.A.3.b.i, 1.A.3.b.ii, 1.A.3.b.iii, 1.A.3.b.iv - Road transport, Table 3-8: HDV, Diesel

⁷ tier1 value derived from ¹⁵⁾

¹⁶⁾ ¹⁷⁾ ¹⁸⁾ ¹⁹⁾ ²⁰⁾ ²¹⁾ ²²⁾ ²³⁾ ²⁴⁾ [IMO2014> IMO, 2014:

[https://arquivo.pt/wayback/20141223211746/http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-\(SOx\)-%e2%80%93Regulation-14.aspx](https://arquivo.pt/wayback/20141223211746/http://www.imo.org/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Sulphur-oxides-(SOx)-%e2%80%93Regulation-14.aspx)]

¹⁾, ³⁾, ¹⁶⁾ AGEB, 2022: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen (Hrsg.), AGEB): Energiebilanz für die Bundesrepublik Deutschland; URL: <http://www.ag-energiebilanzen.de/7-0-Bilanzen-1990-2019.html>, (Aufruf: 23.11.2021), Köln & Berlin, 2022

²⁾, ¹⁷⁾ BAFA, 2022: Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA): Amtliche Mineralöl-daten für die Bundesrepublik Deutschland; URL: https://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_amtliche_daten_2018_dezember.html, Eschborn, 2022.

⁴⁾, ¹⁸⁾ Knörr et al. (2021a): Knörr, W., Heidt, C., Gores, S., & Bergk, F.: ifeu Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung Heidelberg gGmbH, ifeu): Fortschreibung des Daten- und Rechenmodells: Energieverbrauch und Schadstoffemissionen des motorisierten Verkehrs in Deutschland 1960-2035, sowie TREMOD, im Auftrag des Umweltbundesamtes, Heidelberg & Berlin, 2022.

⁵⁾, ¹⁹⁾ Deichnik (2021): Aktualisierung und Revision des Modells zur Berechnung der spezifischen Verbräuche und Emissionen des von Deutschland ausgehenden Seeverkehrs. from Bundesamts für Seeschifffahrt und Hydrographie (BSH - Federal Maritime and Hydrographic Agency); Hamburg, 2022.

⁷⁾, ²⁴⁾ Wikipedia, 2023: https://en.wikipedia.org/wiki/Emission_control_area

⁸⁾, ⁹⁾, ¹¹⁾, ¹²⁾, ¹³⁾, ¹⁴⁾, ²⁰⁾, ²²⁾ EMEP/EEA, 2019: EMEP/EEA air pollutant emission inventory guidebook – 2019, Copenhagen, 2019.

¹⁰⁾, ¹⁵⁾, ²³⁾ Rentz et al., 2008: Nationaler Durchführungsplan unter dem Stockholmer Abkommen zu persistenten organischen Schadstoffen (POPs), im Auftrag des Umweltbundesamtes, FKZ 205 67 444, UBA Texte | 01/2008, January 2008 - URL: <http://www.umweltbundesamt.de/en/publikationen/nationaler-durchfuehrungsplan-unter-stockholmer>

²¹⁾ Knörr et al. (2009): Knörr, W., Heldstab, J., & Kasser, F.: Ermittlung der Unsicherheiten der mit den Modellen TREMOD und TREMOD-MM berechneten Luftschadstoffemissionen des landgebundenen Verkehrs in Deutschland; final report; URL: <https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3937.pdf>, FKZ 360 16 023, Heidelberg & Zürich, 2009.