1.B.2.a - Oil

Category Code	Method	AD	EF
1.B.2.a.i	T2	AS	CS
1.B.2.a.iv	T2	AS	CS
1.B.2.a.v	T2	AS	CS

Key Category	NOx	NMVOC	SO2	NH3	PM2_5	PM10	TSP	BC	CO	PB	Cd	Hg	Diox	PAH	HCB
1.B.2.a.i	-	-/-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.B.2.a.iv	-/-	-/-	-/-	-	-	-	-	-	-/-	-	-	-	-	-	-
1.B.2.a.v	-	-/T	-	-	-	-	-	-	-	-	-	-	-	-	-

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T = key source by Trend **L** = key source by Level

Methods	
D	Default
T1	Tier 1 / Simple Methodology *
T2	Tier 2*
T3	Tier 3 / Detailed Methodology *
C	CORINAIR
CS	Country Specific
M	Model
* as described in the EMEP/EEA Emission Inventory Guidebook - 2019, in the group specific chapters.	

AD - Data Source for Activity Data	
NS	National Statistics
RS	Regional Statistics
IS	International Statistics
PS	Plant Specific data
As	Associations, business organisations
Q	specific Questionnaires (or surveys)
M	Model / Modelled
C	Confidential

EF - Emission Factors	
D	Default (EMEP Guidebook)
C	Confidential
CS	Country Specific

PS	Plant Specific data
M	Model / Modelled

1.B.2.a.i - Exploration, production, transport

Emissions from exploration consist of emissions from activities of drilling companies and other actors in the exploration sector. Gas and oil exploration takes place in Germany. According to the BVEG (former WEG) 1), virtually no fugitive emissions occur in connection with drilling operations, since relevant measurements are regularly carried out at well sites (with use of methane sensors in wellhead-protection structures, ultrasound measurements and annulus manometers) and old / decommissioned wells are backfilled and normally covered with concrete caps.

Table 1: Activity data applied for emissions from oil exploration

	Unit	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
number of wells	No.	12	17	15	23	16	18	12	8
total of drilling meter	m	50,140	109,187	41,378	63,994	51,411	32,773	6,220	8,740

Since pertinent measurements are not available for the individual wells involved, a conservative approach is used whereby VOC emissions for wells are calculated on the basis of the share ratio of VOC = 9 NMVOC : 1 CH4, using the default methane factor of the IPCC Guidelines 2006 2).

Table 2: NMVOC emission factor applied for emissions from oil exploration, in [kg/No.]

Value
576

Emissions from extraction (crude oil) and first treatment of raw materials (petroleum) in the petroleum industry are included in 1.B.2.a.i as well. Because Germany's oil fields are old, oil production in Germany is highly energy-intensive (thermal extraction, operation of pumps to inject water into oil-bearing layers). The first treatment that extracted petroleum (crude oil) undergoes in processing facilities serves the purpose of removing gases, water and salt from the oil. Crude oil in the form present at wellheads contains impurities, gases and water and thus, does not conform to requirements for safe, easy transport in pipelines. No substance transformations take place. Impurities – especially gases (petroleum gas), salts and water – are removed in order to yield crude oil of suitable quality for transport in pipelines.

Table 3: Annual amounts of oil produced, in [kt]

1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
3,606	2,959	3,123	3,573	2,516	2,414	1,907	1,804

The emissions from production and processing are measured or calculated by the operators, and the pertinent data is published in the annual reports of the Federal association of the natural gas, oil and geothermal energy industries (BVEG) 3). The emission factors are determined from the reported emissions and the activity data.

Table 4: NMVOC emission factor applied for emissions from oil production, in [kg/m³]

Value
0.079

Transport emissions are tied to activities of logistics companies and of pipeline operators and pipeline networks. After the first treatment, crude oil is transported to refineries. Almost all transport of crude oil takes place via pipelines. Pipelines are stationary and, normally, run underground. In contrast to other types of transport, petroleum transport is not interrupted by handling processes.

Table 5: Activity data applied for emissions from oil transportation, in [kt]

Activity	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2021**
Transport of domestically produced crude oil	3,660	2,940	3,123	3,572	2,516	2,414	1,907	1,804
Transport of imported crude oil	84,043	86,063	89,280	97,474	93,270	91,275	83,049	81,402
Transport via inland-waterway tankers	89	67	112	176	6	43	46	64

For pipelines, the emission factor for inland-waterway tankers has been estimated by experts. The pertinent emission factors have been confirmed by the research project “Determination of emission factors and activity data in areas 1.B.2.a.i through vi” [4]. Since long-distance pipelines are continually monitored and disruptive incidents in such pipelines are very rare [5], emissions occur – in small quantities – only at their transfer points. The emission factor is thus highly conservative. The emission factor covers the areas of transfer / injection into pipelines at pumping stations, all infrastructure along pipelines (connections, control units, measuring devices), and transfer at refineries, and it has been determined on the basis of conservative assumptions. For imported quantities, only one transfer point (the withdrawal station) is assumed, since the station for input into the pipeline network does not lie on Germany's national territory.

Table 6: NMVOC emission factor applied for emissions from oil transportation, in [kg/t]

Activity	**Value**
Transports of domestically produced crude oil	0.13
Transports of imported crude oil	0.064
Transports via inland-waterway tankers	0.34

1.B.2.a.iv- Refining / storage

Emissions in category 1.B.2.a.iv - Refining / storage consist of emissions from activities of refineries and of refining companies in the petroleum industry. Crude oil and intermediate petroleum products are processed in Germany. For the most part, the companies concerned receive crude oil for refining and processing. To some extent, intermediate petroleum products undergo further processing outside of refineries in processing networks. Such processing takes place in state-of-the-art plants.

Refinery tank storage systems are used to store both crude oil and intermediate and finished petroleum products. They thus differ from non-refinery tank storage systems in terms of both the products they store and the quantities they handle. Tank-storage facilities outside of refineries are used especially for interim storage of heating oil, gasoline and diesel fuel. The storage capacities of storage caverns for petroleum products are listed separately. In light of the ways in which storage caverns are structured, it may be assumed that no emissions of volatile compounds occur. This is taken into account in the emissions calculation.

Tanks are emptied and cleaned routinely before tank inspections and repairs. In tank cleaning, a distinction is made between crude-oil tanks and product tanks. Because sediments accumulate in crude oil tanks, cleaning these tanks, in comparison to cleaning product tanks, is a considerably more laborious process. The substances in product tanks produce no sediments and thus are cleaned only when the products they contain are changed. In keeping with an assessment of Müller-BBM (2010)[6], the emission factors for storage of crude oil and of petroleum products may be assumed to take the cleaning processes into account.

Table 8: Activity data applied for emissions from oil refinement and storage

Activity	**unit**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2019**	**2020**
Quantity of crude oil refined	kt	107,058	96,475	107,632	114,589	95,378	93,391	87,013	83,990
Capacity utilisation in refineries	%	106	92	95	99	81	91	85	85
Crude-oil-refining capacity in refineries	kt	100,765	104,750	112,940	115,630	117,630	103,080	102,655	105,655

Activity	unit	1990	1995	2000	2005	2010	2015	2019	2020
Tank-storage capacity in refineries and pipeline terminals	Mill m³	27,1	28,4	24,9	24	22,5	22	20,7	20,7
Storage capacity of tank-storage facilities outside of refineries	Mill m³	15,4	15,9	18,1	17	15,9	15,3	15,4	15,3
Storage capacity of caverns	Mill m³	26,6	25,3	27,9	27,2	27,2	25,5	26,7	25,5

Processing The emission factors used for NMVOC, CO, NO_x and SO_2 were determined by evaluating the emission declarations of the period 2004 through 2016 in the framework of a research project (Bender & von Müller, 2019) 7).

Tank-storage facilities in refineries

In keeping with the results of the research project “Processing of data of emissions declarations pursuant to the 11th Ordinance Implementing the Federal Immission Control Act – the area of storage facilities” (Müller-BBM, 2010) 8), the crude-oil-distillation capacity is used as the activity data for estimating emissions from storage in refineries. The fugitive VOC emissions value specified in the VDI Guideline 2440 9), 0.16 kg/t, may be used as the emission factor. The EF for methane was derived from it (5-10 % of 0.16 kg) and then suitably deducted.

Tank-storage facilities outside of refineries

According to Müller-BBM (2010) 10), no emission factors could be derived by evaluating emission declarations for storage systems, which would be representative of individual systems. This is due, according to the same source, to the widely differing emission behaviours of different individual systems. It was possible, however, to form aggregated emission factors. For each relevant group of data, this was done by correlating the sums of all emissions with the sums of all capacities. For non-refinery tank-storage systems, storage of liquid petroleum products can be differentiated from storage of gaseous petroleum products, since the relevant data is suitably differentiated.

Claus plants

The emission factors used for NMVOC, CO, NO_x und SO_2 were determined by evaluating emission declarations from refineries for the period 2004 through 2016, in the framework of a research project (Bender & von Müller, 2019)11). Since no data was available for earlier years, the data obtained this way was used for all years as of 1990.

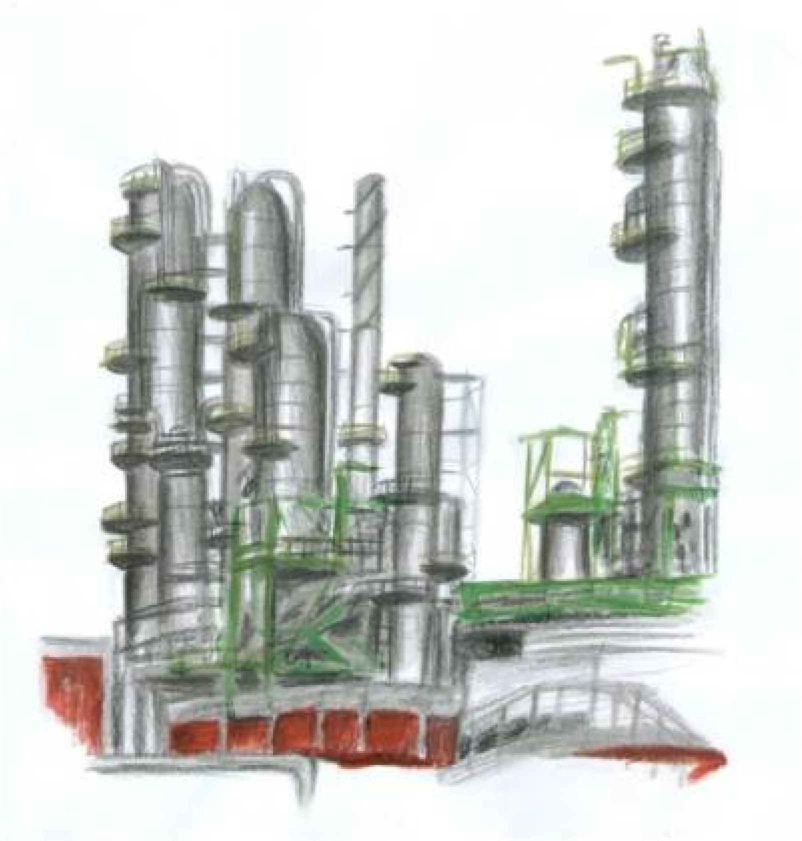

Table 9: Emission factors applied for emissions from oil refinement and storage

Activity	Substance	Unit	Value
Fugitive emissions at refineries	NMVOC	kg/t	0.0072
Fugitive emissions at refineries	NO_x	kg/t	0.00602
Fugitive emissions at refineries	SO_2	kg/t	0.00085
Fugitive emissions at refineries	CO	kg/t	0.000494
Storage and cleaning of crude oil in tank-storage facilities of refineries	NMVOC	kg/t	0.0227
Storage of liquid petroleum products in tank-storage facilities outside of refineries	NMVOC	g/m^3	100
Storage of gaseous petroleum products in tank-storage facilities outside of refineries	NMVOC	g/m^3	500
Claus Plants	NMVOC	kg/t	0.000025
Claus Plants	NO_x	kg/t	0.0022
Claus Plants	SO_2	kg/t	0.048
Claus Plants	CO	kg/t	0.0036

Emissions from storage consider all refinery products. According to the EMEP guidebook, fuel-related emissions are reported under 1.B.2. Emissions other than fuels (like naphtha, methanol etc.) are reported under 2.B.10.b - Storage, Handling and Transport of Chemical Products.

1.B.2.a.v- Distribution of oil products

In category 1.B.2.a.v - Distribution of oil products, the emissions from distribution of oil products are described. Petroleum products are transported by ship, product pipelines, railway tanker cars and tanker trucks, and they are transferred from tank to tank. The main sources of NMVOC emissions from petrol distribution as a whole were fugitive emissions from handling and transfer (filling/unloading) and container losses (tank breathing). Experts consider the emissions from aircraft refuelling to be non-existent, since the equipment used for such refuelling is fitted with dry couplings. The emissions from filling private heating-oil tanks are also very low thanks to high safety standards. In this category, petroleum products that have undergone fractional distillation in refineries are handled and distributed, i.e. processes in which gaseous products are separated out. For this reason, no significant methane emissions are expected. Only in storage of certain petroleum products can small quantities of methane escape.

Table 10: Annual activity data for the distribution of oil products

Activity	Unit	1990	1995	2000	2005	2010	2015	2019	2020
number of petrol stations	No	19,317	17,957	16,324	15,187	14,744	14,531	14,449	14,459
distribution of diesel	kt	21,817	26,208	28,922	28,531	32,128	36,756	37,848	35,163
distribution of jet fuel	kt	4,584	5,455	6,939	8,049	8,465	8,550	10,239	4,725
distribution of light heating oil	kt	31,803	34,785	27,875	25,380	21,005	16,127	15,061	15,558
distribution of domestic petrol	kt	31,257	30,333	28,833	23,431	19,634	18,226	17,966	16,218

Transport

Inland-waterway gasoline tankers retain considerable quantities of gasoline vapours in their tanks after their gasoline has been unloaded. When the ships change loads or spend time in port, their tanks have to be ventilated. With such ships being ventilated on average 277 times per year, the quantity of NMVOC emitted in these operations amounts to 336 - 650 t [12]. The highest value in the range is used to calculate the relevant emissions. About 13 million m^3 of gasoline fuel are transported annually in Germany via railway tank cars. Transfer/handling (filling/unloading) and tank losses result in annual emissions of only 1,400 t VOC [13]. The emissions situation points to the high technical standards that have been attained in railway tank cars and pertinent handling facilities.

Filling stations

Significant quantities of fugitive VOC emissions are released into the environment during transfers from tanker vehicles to storage facilities and during refuelling of vehicles. To determine emissions, a standardised emission factor of 1.4 kg/t is used. This value refers to the saturation concentration for hydrocarbon vapours and thus, corresponds to the maximum possible emissions level in the absence of reduction measures. The immission-control regulations issued in 1992 and 1993 (20th BImSchV [14]; 21st BImSchV, [15]) that required filling stations to limit such emissions promoted a range of reduction measures. The relevant reductions affect both the area of gasoline transfer and storage (20th BImSchV) and the area of fuelling of vehicles with gasoline at filling stations (21st BImSchV). The use of required emissions-control equipment, such as vapour-balancing (20th BImSchV) and vapour-recovery (21st BImSchV) systems, along with the use of automatic monitoring systems (via the amendment of the 21st BImSchV on 6 May 2002), have brought about continual reductions of VOC emissions; the relevant high levels of use of such equipment are shown in the table below (Table 151). In emissions calculation, the two ordinances' utilisation and efficiency requirements for filling stations in service are taken into account. The following assumptions, based on the technical options currently available, are applied:

Ordinance	**Factor**		
20th BImSchV	Vapour balancing	Degree of utilisation	98 %
20th BImSchV	Vapour balancing	Efficiency	98 %
21st BImSchV	Vapour recovery	Degree of utilisation	98 %
21st BImSchV	Vapour recovery	Efficiency	85 %

In addition, permeation of hydrocarbons occurs in tank hoses. The DIN EN 1360 standard sets a limit of 12 ml / hose meter per day for such permeation. From analysis of measurements, UBA experts have adopted a conservative factor of 10ml/m per day. That factor is used to determine the NMVOC emissions. The calculation is carried out in accordance with the pertinent formula of the University of Stuttgart's Institute for Machine Components [16]:

> Number of service stations * number of fuel pumps per service station * number of hoses per fuel pump * hose length * emission factor.

Cleaning of transport vehicles

Tank interiors are cleaned prior to tank repairs and safety inspections, in connection with product changes and with lease changes. The inventory currently covers cleaning of railway tank cars. The residual amounts remaining in railway car tanks after these have been emptied – normally, between 0 and 30 litres (up to several hundred litres in exceptional cases) – are not normally able to evaporate completely. They thus produce emissions when the insides of tanks are cleaned. Each year, some 2,500 cleaning operations are carried out on railway tank cars that transport gasoline. The emissions released, via exhaust air, in connection with cleaning tank cars' interiors amount to about 40,000 kg/a VOC (Joas et al., 2004), p. 34. [17]. Any additional prevention and reduction measures could affect emissions in this category only slightly. At the same time, emissions can be somewhat further reduced from their current levels via a combination of various technical and organizational measures. Emissions during handling – for example, during transfer to railway tank cars – are produced especially by residual amounts of gasoline that remain after tanks have been emptied. Such left-over quantities in tanks can release emissions via manholes the next time the tanks are filled. A study is thus underway to determine the extent to which "best practice" is being followed at all handling stations, and whether this extent has to be taken into account in emissions determination. In addition, improvements of fill nozzles enhance efficiency in prevention of VOC emissions during refuelling. Pursuant to the UBA text (Joas et al., 2004), [18] a total of 1/3 of all relevant transports are carried out with railway tank cars. The remaining 2/3 of all transports are carried out by other means – primarily with road tankers. The 1/3 to 2/3 relationship given by the report is assumed to be also applicable to the emissions occurring in connection with cleaning. Currently, the inventory includes 36,000 kg of NMVOC emissions from cleaning of railway tank cars. Emissions from cleaning of other transport equipment – primarily road tankers – are derived from that figure; they amount to about 70,000 kg NMVOC. More-thorough emissions collection upon opening of manholes of railway tank cars (a volume of about 14.6 m³ escapes), along with more thorough treatment of exhaust from cleaning tank interiors, could further reduce VOC emissions. Exhaust cleansing is assumed to be carried out via one-stage active-charcoal adsorption. For an initial load of 1 kg/m³, exhaust concentration levels can be reduced by 99.5 %, to less than 5 g/m³. As a result, the remaining emissions amount to only 1.1 t. This is equivalent to a reduction of about 97 % from the determined level of 36.5 t/a (without adsorption) (Joas et al. (2004), p. 34) [19].

Generally, the emission factors listed below have been verified by the study [20].

Process responsible for NMVOC emissions		**Emission factor [kg/t]**
Drip losses in refuelling at filling stations	gasoline	0.117
Transfers from road tankers to filling stations (20th Ordinance Implementing the Federal Immission Control Act – vapour displacement)	gasoline	1.4
Ventilation in connection with transports with inland-waterway tankers	gasoline	0.025
Transfers from filling station tanks to vehicle tanks (21st Ordinance Implementing the Federal Immission Control Act – vapour recovery)	gasoline	1.4
Drip losses in refuelling at filling stations	diesel	0.1
Transports from refineries to transport vehicles	diesel	0.008

Process responsible for NMVOC emissions		**Emission factor [kg/t]**
Transfers from filling-station tanks to vehicle tanks	diesel	0.003
Drip losses in refuelling at transfer stations	light heating oil	0.0011
Transports from refineries to transport vehicles	light heating oil	0.0053
Transfers from filling-station tanks to vehicle tanks	light heating oil	0.0063

Recalculations

Please refer to overarching chapter 1.B - Fugitive Emissions from fossil fuels

Planned improvements

No further improvements are planned.

References

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[1] WEG (2008). Report of the Association of Oil and Gas Producing “Erdgas – Erdöl. Entstehung-Suche-Förderung”, Hannover, 34 S. External Link, PDF

[2] IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. External Link

[3] BVEG (2019). Annual report of the Association of Oil and Gas Producing “Die E&P-Industrie in Zahlen. Statisticher Bericht 2019: Zahlen”. External Link

[4], [20] Theloke, J., Kampffmeyer, T., Kugler, U., Friedrich, R., Schilling, S., Wolf, L., & Springwald, T. (2013). Ermittlung von Emissionsfaktoren und Aktivitätsraten im Bereich IPCC (1996) 1.B.2.a. i-vi - Diffuse Emissionen aus Mineralöl und Mineralölprodukten (Förderkennzeichen 360 16 033). Stuttgart.

[5] Cech, M., Davis, P., Gambardella, F., Haskamp, A., González, P. H., Spence, M., & Larivé, J.-F. (2017). Performance of European cross-country oil pipelines - Statistical summary of reported spillages in 2015 and since 1971 External Link

[6], [8], [10] Müller-BBM (2010). UBA research project No. 3707 42 103/ 01, Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV aus dem Jahre 2004 für die Verwendung bei der UNFCC- und UNECE-Berichterstattung - Bereich Lageranlagen (Bericht Nr. M74 244/7, UBA FKZ 3707 42 103/01). External Link

[7], [11] Bender, M., & von Müller, G. (2019). Konsolidierung der Treibhausgasemissionsberechnungen unter der 2. Verpflichtungsperiode des Kyoto-Protokolls und der neuen Klimaschutz-Berichterstattungspflichten an die EU (FKZ 3716 41 107 0).

[9] VDI (2000). VDI-Richtlinie 2440: Emissionsminderung - Mineralölraffinerien, published by V. D. I.

[12] Bauer, S., Polcher, D. A., & Greßmann, A. (2010). Evaluierung der Anforderungen der 20. BImSchV für Binnentankschiffe im Hinblick auf die Wirksamkeit der Emissionsminderung klimarelevanter Gase (FKZ 3709 45 326). München.

[13], [17], [18], [19] Dr. R. Joas; A. Potrykus; R. Schott; S. Wenzel (2004). “VOC-Minderungspotenzial beim Transport und Umschlag von Mineralölprodukten mittels Kesselwagen”, FKZ 202 44 372, UBA-Texte 12/2004, Dessau. External Link

[14] 20. BImSchV - Zwanzigste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes (Verordnung zur Begrenzung der Emissionen flüchtiger organischer Verbindungen beim Umfüllen oder Lagern von Ottokraftstoffen, Kraftstoffgemischen oder Rohbenzin) in der Fassung der Bekanntmachung vom 18. August 2014(BGBl. I S. 1447), die durch Artikel 2 der Verordnung vom 24. März 2017 (BGBl. I S. 656) geändert worden ist, published by BGBl (2017).

[15] 21. BImSchV - Verordnung zur Begrenzung der Kohlenwasserstoffemissionen bei der Betankung von Kraftfahrzeugen in der Fassung der Bekanntmachung vom 18. August 2014 (BGBl. I S. 1453), die zuletzt durch Artikel 3 der Verordnung vom 24. März 2017 (BGBl. I S. 656) geändert worden ist, published by BGBl. (2017).

[16] Haas, W. (2015). Kraftstoffpermeation an Zapfsäulen.