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Life cycle inventories of long-distance transport of crude oil

Federal Office for the Environment (FOEN)

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Report

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Abbreviations

a	year (annum)
API	American Petroleum Institute
AZ	Azerbaijan
bbl	Barrel
bcm	billion cubic meters
BOD5	Biochemical oxygen demand for 5 days of microbial degradation
BTU	British Thermal Unit (1 BTU = 1055 J)
BTX	Benzene, Toluene, and Xylenes
Bq	Becquerel
CH_4	Methane
CHP	Combined Heat and Power
CIS	Commonwealth of Independent States
CMC	Carboxymethyl Cellulose
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
Concawe	Conservation of Clean Air and Water in Europe (the oil companies' European organization for environmental and health protection, established in 1963)
d	day
DeNOx	Denitrification method (general)
DM	Dry matter
DoE	Department of Energy, US
dwt	Dead weight tons
DZ	Algeria
E5/10/15/85•	Petrol with 5%/10%/15%/85% ethanol
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency, US
FGD	Flue Gas Desulphurisation system
GGFR	Global Gas Flaring Reduction Partnership
GRT	Gross Registered Tonne
GWP	Global Warming Potential
HC	Hydrocarbons
HEC	Hydroxyethyl cellulose
IEA	International Energy Agency
IMO	International Maritime Organization
IPCC	International Panel on Climate Change
IQ	Iraq
J	Joule
KBOB	Koordinationsgremium der Bauorgane des Bundes
KZ	Kazakhstan
LCI	Life cycle inventory analysis
LCIA	Life cycle impact assessment
MEEPD	Ministry of the Environment, Environmental Protection Department
M.	Million
MJ	Megajoule
Mt	Megaton = 1 million tons
MTBE	Methyl tert-butyl ether

MW	Megawatt
MX	Mexico
NCI	Nelson complexity index
NER	Net Energy Return
NG	Nigeria
NGL	Natural Gas Liquids
NL	Netherlands
Nm^3	Normal-cubic metre (for gases)
NMVOC	Non-Methane-Volatile Organic Compounds
NO	Norway
NOAA	National Oceanic and Atmospheric Administration
NOX	Nitrogen oxides
NR	Not Reported
Ns	not specified
OBM	Oil Based Mud,
OE	Oil equivalent
OECD	Organisation for Economic Cooperation and Development
PAH	Polycyclic Aromatic Hydrocarbons
PC	Personal Communication
PM	Particulate Matter
Rn	Radon
RODP	Relative Ozone Depletion Potential
RU	Russia
SA	Saudi-Arabia
SEPL	South European Pipeline
SPCA	State Pollution Control Authority
TDS	Total Dissolved Solids
toe	Ton Oil Equivalent
TSP	Total Suspended Particulates
TSS	Total Suspended Solids
UCTE	Union for the Co-ordination of Transmission of Electricity
ULCC	Ultra Large Crude Carrier
UNEP	United Nations Environment Programme
US (A)	United States of America
UVEK	Federal Department for Environment, Transport, Energy and Communications
Works)	
VLCC	Very Large Crude Carrier
VOC	Volatile Organic Compounds
WEC	World Energy Council

1 Introduction

The goal of this study is to document the life cycle inventory data as submitted to Federal Office for the Environment (FOEN) for the implementation in their latest database release. Changes made by the commissioner to implement the data in their database are not described in this report. The content of this document therefore might not fully reflect the LCI data as provided with the database of the commissioner.

This document is based on the previous update of the life cycle inventory data for long-distance transport of crude oil (Meili et al. 2021). Former versions of this report have been elaborated in a project for updating and harmonizing the life cycle inventories in the UVEK database (UVEK 2018). There the focus was on analysing the long-distance crude oil transport from the perspective of production regions relevant for Switzerland, Europe, North America and the global situation. Later, the model was extended to cover the perspective of other countries/regions as well.

For this report, the perspective of the countries and regions listed in Tab. 1.1 is modelled for the reference year 2023.

In a related project, the reports for the oil and gas extraction (Meili et al. 2025) the transport of natural gas to the end user (Bussa et al. 2025) and the production of plastics (Rajabihamedani et al. 2025) are updated as well.

The investigation starts at the oil field in countries of origin and ends with the delivery of crude oil to a theoretical refinery at a specific country or region.

To simplify modelling, aggregated datasets for crude oil import mix to the analysed countries or regions are generated.For the infrastructure, the formerly consulted literature information on data for pipelines, relevant for the environment (specific energy demand, emissions to air and water, maintenance, energy carrier of pipeline driving systems etc.) is assumed to be still valid (c.f. Jungbluth 2007) and no update was commissioned for this.

Tab. 1.1 Countries and world regions for which crude oil markets are modelled in this study. Port of destination assumed for the global transport model and amount of crude oil extracted, imported, and exported for the reference year 2023, in kg (estimates based on EI 2024 and Avenergy_Suisse 2024). Total of country specific markets analysed = sum of values above except the ones for the regions *Europe, North America & Global)*

	Port of destination	Crude oil extracted	Crude oil imported	Crude oil exported	Crude oil on market
Unit		kg	kg	kg	kg
Europe	*Rotterdam*	*1.52E+11*	*4.37E+11*	*1.21E+10*	*5.77E+11*
North America	*Houston*	*1.21E+12*	*3.49E+11*	*4.46E+11*	*1.11E+12*
United Arab Emirates	Dubai or Abu Dhabi	1.76E+11	7.91E+09	1.71E+11	1.32E+10
Australia	Perth	1.57E+10	8.38E+09	1.00E+10	1.40E+10
Belgium	Antwerp	3.75E+07	2.18E+10	2.99E+06	2.18E+10
Brazil	Santos	1.84E+11	5.40E+09	6.86E+10	1.21E+11
Canada	Quebec	2.78E+11	2.50E+10	2.07E+11	9.57E+10
Switzerland	Marseille	0.00E+00	2.70E+09	0.00E+00	2.70E+09
China	Guangdong	2.09E+11	5.64E+11	1.18E+09	7.72E+11
Colombia	Tumaco	4.09E+10	0.00E+00	1.53E+10	2.57E+10
Germany	Hamburg	2.90E+09	7.43E+10	2.31E+08	7.70E+10
Algeria	Algiers	6.04E+10	0.00E+00	2.85E+10	3.19E+10
Spain	Castellon	9.86E+05	5.00E+10	1.57E+05	5.00E+10
France	Marseille	8.29E+08	5.24E+10	6.61E+07	5.32E+10
United Kingdom	Southampton	3.34E+10	2.58E+10	2.67E+09	5.66E+10
Indonesia	Tanjung Priok	3.12E+10	5.77E+10	2.40E+10	6.48E+10
India	Mumbai	3.26E+10	2.31E+11	1.90E+09	2.62E+11
Iran	Bahregan Sar Oilfield	2.14E+11	0.00E+00	5.46E+10	1.60E+11
Italy	Trieste	4.31E+09	4.47E+10	3.44E+08	4.86E+10
Japan	Tokyo	3.21E+08	1.26E+11	1.60E+04	1.26E+11
South Korea	Inchon	5.44E+08	1.11E+11	4.19E+08	1.11E+11
Kuwait	Shuaiba	1.40E+11	0.00E+00	8.11E+10	5.86E+10
Mexico	Veracruz	1.03E+11	1.40E+06	5.38E+10	4.88E+10
Netherlands	Rotterdam	7.12E+08	3.18E+10	5.68E+07	3.25E+10
Peru	Callao	5.15E+09	1.42E+10	1.92E+09	1.74E+10
Qatar	Halul Island	7.41E+10	0.00E+00	1.89E+10	5.52E+10
Russian Federation	St. Petersburg	5.42E+11	7.65E+09	2.41E+11	3.09E+11
Saudi Arabia	Ju' aimah	5.32E+11	0.00E+00	3.49E+11	1.83E+11
Singapore	Singapore	0.00E+00	4.23E+10	1.97E+09	4.03E+10
Thailand	Sriracha Oil terminals	1.12E+10	4.53E+10	8.63E+09	4.79E+10
Turkey	Gemlik	4.62E+09	9.28E+09	3.55E+09	1.03E+10
Taiwan	Kaohsiung	5.76E+08	3.38E+10	4.43E+08	3.39E+10
United States	Houston	8.27E+11	3.24E+11	1.85E+11	9.66E+11
South Africa	Cape Town	4.89E+09	3.55E+09	0.00E+00	8.43E+09
Global	-	***4.51E+12***	***2.13E+12***	***2.13E+12***	***4.51E+12***
Total of country specific markets analysed		3.53E+12	1.92E+12	1.53E+12	3.92E+12
Share of country specific markets analysed on global market		78.3%	90.2%	72.0%	86.9%

2 Market situation

To represent the market situation in 2023, international trade data is used in the model (EI 2024). For the situation in Switzerland, data is taken from the annual report of Avenergy_Suisse 2024. In the following sub-chapters, examples are shown for the considered data for the market situation in Switzerland, the EU-28-states and the global situation.

2.1 Switzerland

In 2023, no crude oil is extracted in or exported from Switzerland. Crude oil is only imported to Switzerland from the countries listed in Tab. 2.1. For all these countries extraction data is modelled and updated for the reference year 2023. Typical properties of crude oil are provided in the report on oil extraction (c.f. Meili et al. 2025).

Tab. 2.1 Amount and share of crude oil imported to Switzerland in 2023, by country of origin (Avenergy_Suisse 2024).

	Origin of crude oil transported to Switzerland	crude oil imported	Share for import mix in 2023
		thousand tons	Mass fraction (%)
1	**United States**	1’488	55.0%
2	**Nigeria**	870	32.2%
3	**Algeria**	184	6.8%
4	**Libya**	115	4.3%
5	**Kazakhstan**	48	1.8%
	Total	**2’704**	**100.0%**

2.2 EU-28

Some of the EU-28 countries extracted and exported crude oil in 2023. Additionally, the EU-28 countries imported crude oil from different countries (EI 2024). To build a market mix, the locally extracted and imported crude oil is added up and the exported crude oil is subtracted. Tab. 2.2 shows the amount of crude oil extracted in and exported from EU-28 countries for which specific extraction data is modelled and updated for the reference year 2023 (Meili et al. 2025). Also shown is the amount of crude oil imported from outside of the EU-28, for countries of which specific extraction data is modelled and updated for the reference year 2023 (Meili et al. 2025). In total about 75% of the crude oil refined in EU-28 countries is imported. The modelled countries cover about 90% of the market mix of the EU-28 countries.

Tab. 2.2 Amount of crude oil extracted in, imported to and exported from EU-28 countries (EI 2024). Only amounts for countries for which extraction data is modelled in the LCI for 2023 are shown and summed up in "Total covered" (Meili et al. 2025).

Origin of crude oil refined in the European Union	Extracted in EU	Import to EU	Export from EU	Market (refined in EU)	Share (refined in EU)
Unit	kg	kg	kg	kg	%
United Arab Emirates	0	5.44E+09	0	5.44E+09	1.03%
Argentina	0	2.47E+09	0	2.47E+09	0.47%
Australia	0	6.10E+07	0	0	0.00%
Azerbaijan	0	1.72E+10	0	1.72E+10	3.25%
Belgium	3.75E+07	0	2.99E+06	0	0.00%
Bolivia	0	5.79E+07	0	0	0.00%
Brazil	0	8.84E+09	0	8.84E+09	1.67%
Canada	0	6.70E+09	0	6.70E+09	1.27%
China	0	4.21E+08	0	4.21E+08	0.08%
Colombia	0	1.97E+09	0	1.97E+09	0.37%
Germany	2.90E+09	0	2.31E+08	2.67E+09	0.50%
Algeria	0	2.13E+10	0	2.13E+10	4.02%
Ecuador	0	1.23E+09	0	1.23E+09	0.23%
Egypt	0	1.05E+10	0	1.05E+10	1.99%
Spain	9.86E+05	0	7.85E+04	0	0.00%
France	8.29E+08	0	6.61E+07	7.63E+08	0.14%
United Kingdom	3.34E+10	0	2.67E+09	3.08E+10	5.82%
Indonesia	0	2.51E+08	0	0	0.00%
India	0	1.90E+09	0	1.90E+09	0.36%
Iraq	0	4.92E+10	0	4.92E+10	9.30%
Iran	0	1.07E+09	0	1.07E+09	0.20%
Italy	4.31E+09	0	3.44E+08	3.97E+09	0.75%
Japan	0	4.00E+00	0	0	0.00%
South Korea	0	4.38E+06	0	0	0.00%
Kuwait	0	3.39E+09	0	3.39E+09	0.64%
Kazakhstan	0	4.79E+10	0	4.79E+10	9.06%
Libya	0	2.11E+10	0	2.11E+10	3.98%
Mexico	0	8.04E+09	0	8.04E+09	1.52%
Malaysia	0	2.06E+08	0	0	0.00%
Nigeria	0	2.64E+10	0	2.64E+10	5.00%
Netherlands	7.12E+08	0	5.68E+07	6.55E+08	0.12%
Norway	9.47E+10	0	7.55E+09	8.72E+10	16.48%
Oman	0	2.52E+08	0	0	0.00%
Peru	0	2.48E+08	0	0	0.00%
Poland	1.39E+09	0	1.11E+08	1.28E+09	0.24%
Qatar	0	3.69E+08	0	0	0.00%
Romania	2.98E+09	0	2.38E+08	2.75E+09	0.52%
Russian Federation	0	3.24E+10	0	3.24E+10	6.12%
Saudi Arabia	0	4.07E+10	0	4.07E+10	7.70%
Thailand	0	9.03E+07	0	0	0.00%
Turkmenistan	0	5.23E+09	0	5.23E+09	0.99%
Turkey	0	3.72E+07	0	0	0.00%
Trinidad and Tobago	0	1.60E+08	0	0	0.00%
Taiwan	0	4.64E+06	0	0	0.00%
Ukraine	2.18E+09	0	1.73E+08	2.00E+09	0.38%
United States	0	8.04E+10	0	8.04E+10	15.19%
Uzbekistan	0	1.12E+09	0	1.12E+09	0.21%
Venezuela	0	2.11E+09	0	2.11E+09	0.40%
Total covered	**1.44E+11**	**3.99E+11**	**1.14E+10**	**5.29E+11**	
Total according to statistics	**1.60E+11**	**4.37E+11**	**1.21E+10**	**5.84E+11**	
Share for LCI (%)	**90%**	**91%**	**95%**	**91%**	**100%**

2.4 Global market

To simplify the modelling of a global market mix, it is assumed, that the globally refined crude oil in 2023 is equal to the extracted crude oil in the same period (EI 2024). For long-distance transportation the amount of imported crude oil to the global region is considered (EI 2024). Tab. 2.4 shows the amount of crude oil extracted in and globally imported from countries for which specific extraction data is modelled and updated for the reference year 2023 (Meili et al. 2025). The modelled countries cover about 96% of the globally extracted crude oil.

If, e.g., due to annual trade imbalances, export in a country or region exceeds extraction rate in the same region, this is corrected by using the value for extraction instead of export. This also means, no physical trade between different countries is assumed.

Tab. 2.4 Amount of crude oil extracted in and imported to global region (EI 2024). Only amounts for countries for which extraction data is modelled in the LCI for 2023 are shown and summed up in "Total covered" (Meili et al. 2025).

Origin of crude oil refined globally	Extracted globally	Imported globally	Market (refined globally)	Share (refined globally)
Unit	kg	kg	kg	%
United Arab Emirates	1.76E+11	1.71E+11	1.76E+11	4.09%
Argentina	5.12E+10	1.91E+10	5.12E+10	1.19%
Australia	1.57E+10	1.00E+10	1.57E+10	0.36%
Azerbaijan	3.02E+10	2.16E+10	3.02E+10	0.70%
Belgium	3.75E+07	2.99E+06	0	0.00%
Bolivia	1.20E+09	4.49E+08	0	0.00%
Brazil	1.84E+11	6.86E+10	1.84E+11	4.27%
Canada	2.78E+11	2.07E+11	2.78E+11	6.46%
China	2.09E+11	1.18E+09	2.09E+11	4.86%
Colombia	4.09E+10	1.53E+10	4.09E+10	0.95%
Germany	2.90E+09	2.31E+08	0	0.00%
Algeria	6.04E+10	2.85E+10	6.04E+10	1.40%
Ecuador	2.55E+10	9.51E+09	2.55E+10	0.59%
Egypt	2.98E+10	1.41E+10	2.98E+10	0.69%
Spain	9.86E+05	7.85E+04	0	0.00%
France	8.29E+08	6.61E+07	0	0.00%
United Kingdom	3.34E+10	2.67E+09	3.34E+10	0.78%
Indonesia	3.12E+10	2.40E+10	3.12E+10	0.72%
India	3.26E+10	1.90E+09	3.26E+10	0.76%
Iraq	2.13E+11	1.84E+11	2.13E+11	4.95%
Iran	2.14E+11	5.46E+10	2.14E+11	4.98%
Italy	4.31E+09	3.44E+08	0	0.00%
Japan	3.21E+08	1.60E+04	0	0.00%
South Korea	5.44E+08	4.19E+08	0	0.00%
Kuwait	1.40E+11	8.11E+10	1.40E+11	3.25%
Kazakhstan	8.42E+10	6.03E+10	8.42E+10	1.96%
Libya	5.97E+10	2.82E+10	5.97E+10	1.39%
Mexico	1.03E+11	5.38E+10	1.03E+11	2.38%
Malaysia	2.55E+10	1.97E+10	2.55E+10	0.59%
Nigeria	7.39E+10	7.37E+10	7.39E+10	1.72%
Netherlands	7.12E+08	5.68E+07	0	0.00%
Norway	9.47E+10	7.55E+09	9.47E+10	2.20%
Oman	5.06E+10	1.29E+10	5.06E+10	1.17%
Peru	5.15E+09	1.92E+09	5.15E+09	0.12%
Poland	1.39E+09	1.11E+08	0	0.00%
Qatar	7.41E+10	1.89E+10	7.41E+10	1.72%
Romania	2.98E+09	2.38E+08	0	0.00%
Russian Federation	5.42E+11	2.41E+11	5.42E+11	12.58%
Saudi Arabia	5.32E+11	3.49E+11	5.32E+11	12.35%
Thailand	1.12E+10	8.63E+09	1.12E+10	0.26%
Turkmenistan	9.19E+09	6.57E+09	9.19E+09	0.21%
Turkey	4.62E+09	3.55E+09	4.62E+09	0.11%
Trinidad and Tobago	3.32E+09	1.24E+09	0	0.00%
Taiwan	5.76E+08	4.43E+08	0	0.00%
Ukraine	2.18E+09	1.73E+08	0	0.00%
United States	8.27E+11	1.85E+11	8.27E+11	19.22%
Uzbekistan	1.97E+09	1.41E+09	0	0.00%
Venezuela	4.37E+10	1.63E+10	4.37E+10	1.02%
Total covered	**4.33E+12**	**2.01E+12**	**4.30E+12**	
Total according to statistics	**4.49E+12**	**2.13E+12**	**4.49E+12**	
Share for LCI (%)	**96%**	**94%**	**96%**	**100%**

2.5 Threshold for considering countries of origin

International trade data shows some aggregated data points for import-export relations, e.g. for imports from "Other Europe" or "Other Asia pacific" (EI 2024). In this study, such aggregated data was allocated proportionally according to region specific extraction data for export and region-specific consumption data for imports. However, to reduce the number of interconnections and complexity in the database, a threshold value was defined to neglect import-, export- and extraction-shares for a specific market if they are below 0.1%.

3 Transport routes

3.1 Import to Switzerland

No changes were made compared to a former study (Meili et al. 2018). According to the refinery in Cressier, all crude oil that is directly imported to Switzerland enters the European mainland through the seaport in Marseille (FR)[1]. The length of the Pipeline is measured with 600 km[2].

3.2 Import to Europe

Crude oil imported for the European average refinery is assumed to be shipped to the European mainland via Rotterdam. Crude oil, which is directly imported onshore, e.g., from Russia, Kazakhstan and Azerbaijan enters Europe on the mainland via pipelines and is assumed to be refined mainly in Eastern European refineries. In this model, for these exceptions, a refinery in Bratislava, Slovakia is assumed for distance calculations.

For crude oil processed directly in the country of origin (e.g., DE, GB, NL) and oil transported by ship, a generic transport distances to a refinery of about 100km is considered.

3.3 Import to North America

Crude oil imported to Northern America is assumed to be shipped to Houston. For crude oil processed directly in the country of origin (CA, MX, US) and oil transported by ship, a generic transport distance to a refinery of about 100km is considered.

3.4 Import to global market

For the countries for which extraction of crude oil is modelled, the weighted transport distance for export to specific countries or global regions is calculated based on global statistics (EI 2024). For each country one single harbour, which is close to local oil fields is chosen as port of origin. For countries that do not extract crude oil, harbours close to refineries are selected. Independent of current trade statistics and local circumstances for each country only one harbour is selected and modelled as origin and destination port.

3.5 Transport from extraction site to port of destination

All distances for transport in pipelines and on open sea are taken from online maps[3,4] and/or from former studies (Jungbluth 2007; Meili et al. 2018; Stolz & Frischknecht 2017).

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1 https://www.srf.ch/news/wirtschaft/was-kommt-nach-dem-erdoel-cressier-die-letzte-erdoel-raffinerie-der-schweiz online 16.12.2020

2 Distance measured on www.maps.google.com, online 05.10.2017.

3 Distances for pipeline transport are taken from: www.maps.google.com, online 05.10.2017.

4 Distances for oceanic transport are taken from www.searates.com, online 05.10.2017 and https://sea-distances.org/, online 23.10.2019.

Different than in former reports, for offshore pipelines in countries with higher share than 50% offshore-production specific estimates are applied. These are mainly based on data from the global energy monitor.[5]

Some exemplary values are shown here:

- Australia (268km)[5]
- Azerbaijan (~43km)[5]
- Nigeria (~60km)[6],
- Norway (195km)[7],
- Qatar (~50km)[5]
- USA (Gulf of Mexico: ~285km)[5]

Where not stated differently, a generic estimate of 100km is used.

For countries, where long distances for pipeline use are assumed, an individual distance for onshore transportation from typical extraction sites to a selected harbour is assessed. The selected harbours do reflect an average origin estimated for the importing region and do not necessarily reflect the harbour from which the highest amount of crude oil is exported. For countries, for which a shorter transport by pipeline is assumed, a generic distance of 100km is used.

To make the model globally consistent, compared to former studies one single harbour per country was selected to be used independent of the destination (Meili et al. 2018). Therefore, e.g., Port of Origin for Russia is St. Petersburg. Port of origin for Kazakhstan is newly assumed to be in Novorossiysk, as this is the nearest port on the black sea which has a high global export capacity (European Commission 2015).

Some exceptional cases are described in the following subchapters.

An overview on modelled transport distances and assumed ports of origin is given for long distance transports of crude oil to Switzerland (Tab. 3.1) and Europe (Tab. 3.2). In Tab. 3.3 also an overview for an estimate for the global market is provided.

3.5.1 Algeria

An average distance of 700km for pipelines from Hassi Messaoud to the port of Algiers is estimated based on a map of current oil fields.[8]

3.5.2 Argentina

An average distance of 500km for pipelines from onshore sites to the coast is estimated based on a map of current oil fields.[9]

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5 Pipeline lengths according to https://globalenergymonitor.org/projects/global-oil-infrastructure-tracker/, online 16.07.2024

6 Offshore pipelines in Nigeria: https://theodora.com/pipelines/nigeria_oil_gas_and_products_pipelines_map.html & https://globalenergymonitor.org/projects/global-oil-infrastructure-tracker/, online 11.07.2024

7 Offshore pipelines in Norway: Weighted average based on flow area and length based on https://www.norskpetroleum.no/en/production-and-exports/the-oil-and-gas-pipeline-system/#oil-pipelines, online 11.07.2024

8 https://energy-cg.com/OPEC/Algeria/Algeria_infra_oilgastransexportMar19_hires_Image1x1_EnergyConsutlingGroup_ppt.png, online 27.02.2023

9 https://www.equinor.com/where-we-are/argentina, online 27.02.2023

3.5.3 Australia

An average distance of 800km for pipelines from onshore sites to the coast is estimated based on a map of current oil fields.[10]

3.5.4 Azerbaijan

Transport through the Baku–Tbilisi–Ceyhan pipeline to the port of Ceyhan in Turkey is assumed for main exports (estimated length: 1800km)[11].

3.5.5 Brazil

An average distance of 800km for pipelines from onshore sites to the coast is estimated based on a map of current oil fields.[12]

3.5.6 Canada

An average distance of 3000km for pipelines from onshore sites to the coast is estimated based on a map of current oil fields.[13]

3.5.7 Colombia

An average distance of 800km for pipelines from onshore sites to the coast is estimated based on a map of current oil fields.[14]

3.5.8 Ecuador

An average distance of 300km for pipelines from onshore sites e.g., near Quito to the coast is estimated based on a map of current oil fields.[15]

3.5.9 India

An average distance of 1000km for pipelines from onshore sites e.g., near Ajmer to the coast is estimated based on a map of current oil fields.[16]

3.5.10 Iran

An average distance of 400km for pipelines from onshore sites e.g., near Ajmer to the coast is estimated based on a map of current oil fields.[17]

3.5.11 Iraq

To be consistent with a global transport model, the average port of origin is assumed to be directly in Iraq, in Basrah. This option is chosen although it is more likely that most crude oil is transported to Europe and

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[10] https://energy-cg.com/Australia/Australia_OilGasOverview_Aug15_Image1x1_EnergyConsutlingGroup_web.png, online 27.02.2023

[11] https://www.azerbaijans.com/content_1030_en.html, online 13.03.2021

[12] https://www.researchgate.net/profile/Gisele_Da_Rocha2/publication/279732210/figure/download/fig4/AS:404577741492232@1473470258586/Map-showing-onshore-and-offshore-Brazilian-Basins-for-conventional-and-unconventional.png, online 27.02.2023

[13] https://energy-cg.com/Canada/Thumbnail_Canada/natural_gas_pipelines.png, online 27.02.2023

[14] https://www.esirgroup.com/images/Colombia_Oil_Gas_Map.jpg, online 27.02.2023

[15] https://images.energy365dino.co.uk/standard/158104_4d84a60850ed4f17b445.jpg, online 27.02.2023

[16] https://iocl.com/images/pipelines-images/ind.jpg, online 27.02.2023

[17] https://www.oilandgas360.com/wp-content/uploads/2015/12/TAFT-Iran-Map.jpg, online 27.02.2023

Switzerland via an onshore pipeline from Bagdad to the port Ceyhan in the south-east of Turkey (European Commission 2017). For pipeline transport to the port, an average distance of 500km is estimated.

3.5.12 Kazakhstan

Crude oil from Kazakhstan is transported via onshore pipeline to the Black Sea. Port of Novorossiysk is assumed to be the main port of origin (European Commission 2015). A 20km offshore pipeline transport is estimated to cover offshore production. For Import to EU-28, no transport by ship is assumed. For this case, the whole transport is done in onshore pipelines. For import to China the direct pipeline to Koria is estimated with a length of 2000km.[19]

3.5.13 Kuwait

As the distance from western boarder to the sea in the east is only about 50km, the average pipeline length for transport is estimated with about 20km.

3.5.14 Libya

An average distance of 200km for pipelines from onshore sites e.g., near Ajmer to the coast is estimated based on a map of current oil fields.[20]

3.5.16 Norway

Crude oils from the North Sea are transported through offshore pipelines with an estimated length of 200km to the Norwegian mainland for reloading to oil tankers in Bergen.

3.5.17 Mexico

For Mexico, 200 km pipeline offshore and 500 onshore are assumed for transports to the harbour. Port for export of crude oil is assumed to be in Veracruz.

3.5.18 Russia

There are various transport routes for Russian crude oils. In addition to the mainland route through the Druzhba pipeline, crude oil can reach Rotterdam in summer via the Baltic Sea or (all year round) via Odessa through the Black Sea to the Mediterranean Sea.

Main crude oil production in Russia with destination Europe is produced in the Ural and western Siberian re gion (European Commission 2015). According to the Harvard World Map[23] (see Fig. 3.1), many large production fields lie in the west and east of Yekaterinburg. Based on this map, it is assumed that oil with destination Europe and Switzerland is produced on average in Yekaterinburg.

For the average European refinery mix it is assumed that crude oil from Russia is mainly refined in Eastern European refineries. As approximation for the destination, the Czech Republic is assumed. This leads to a total of 3800km by pipeline transport onshore. For the transport to Switzerland, to stay consistent with a global transport model, the route with shipping from St. Petersburg to Marseille is modelled. This option is chosen

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18 https://en.wikipedia.org/wiki/Kirkuk%E2%80%93Ceyhan_Oil_Pipeline, online 01.10.2018
19 https://i.insider.com/555365196da8119c29e8a313?width=1000&format=jpeg&auto=webp, online 27.02.2023
20 https://www.worldoil.com/media/15810/libya-map.jpg, online 27.02.2023
21 https://www.export.gov/article?id=Mexico-Upstream-Oil-and-Gas, online 02.10.2017
22 https://oilprice.com/Energy/Crude-Oil/Can-Mexico-Reverse-Its-Steep-Output-Decline.html, online 02.10.2017
23 https://worldmap.harvard.edu/maps/6176, online 18.01.2018

although it is more likely that most crude oil is transported to Switzerland via the Black sea. For transport to China, the Tomsk-Daqing-Pipeline is considered with 2500km.[24]

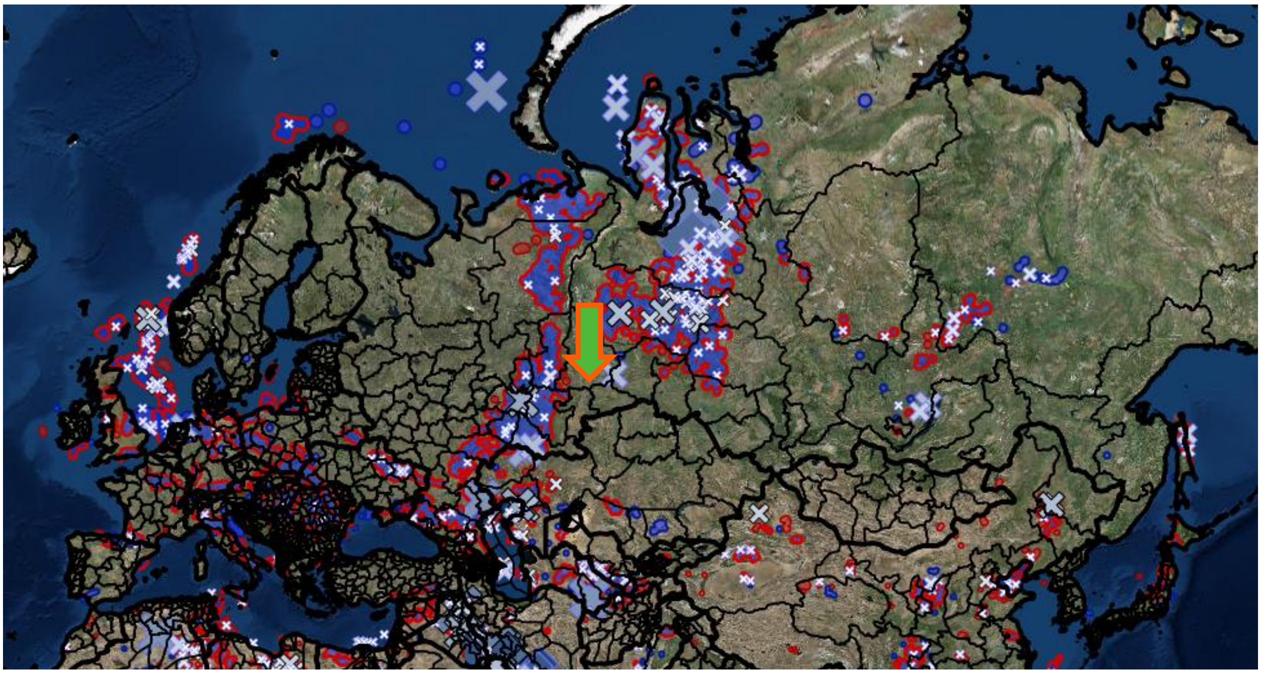

Fig. 3.1 Crude oil production in Russia and Europe according to Harvard World Map.[23] Arrow in orange and green showing Yekaterinburg as assumption for average origin of crude oil imported from Russia to Europe

3.5.19 Saudi Arabia

Saudi-Arabia transfers its pre-treated crude oil from Abqaiq in the West to East (the Red Sea), via the pipeline Abqaiq-Yanbu with a total length of 1300 km.

3.5.20 Turkmenistan

An average distance of 2000km for pipelines from onshore sites to the Caspian Sea is estimated based on a map of current oil fields.[25]

3.5.21 United States of America

For the United States, 1100km onshore pipelines to the port in Houston are estimated based on an online map on drilling sites (Fig. 3.2).

[24] https://i.insider.com/555365196da8119c29e8a313?width=1000&format=jpeg&auto=webp, online 27.02.2023
[25] https://www.eurasiansecurity.com/wp-content/uploads/2015/02/turkmenistan-oil-gas-map.jpg, online 27.02.2023
[26] Imports and Exports 2016: https://www.eia.gov/tools/faqs/faq.php?id=727&t=6, online 13.11.2017
[27] https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm, online 18.01.2018
[28] Drilling Maps: https://www.arcgis.com/home/item.html?id=a03b2e1da77c4c93b7cad628c0f268be, online 13.11.2017

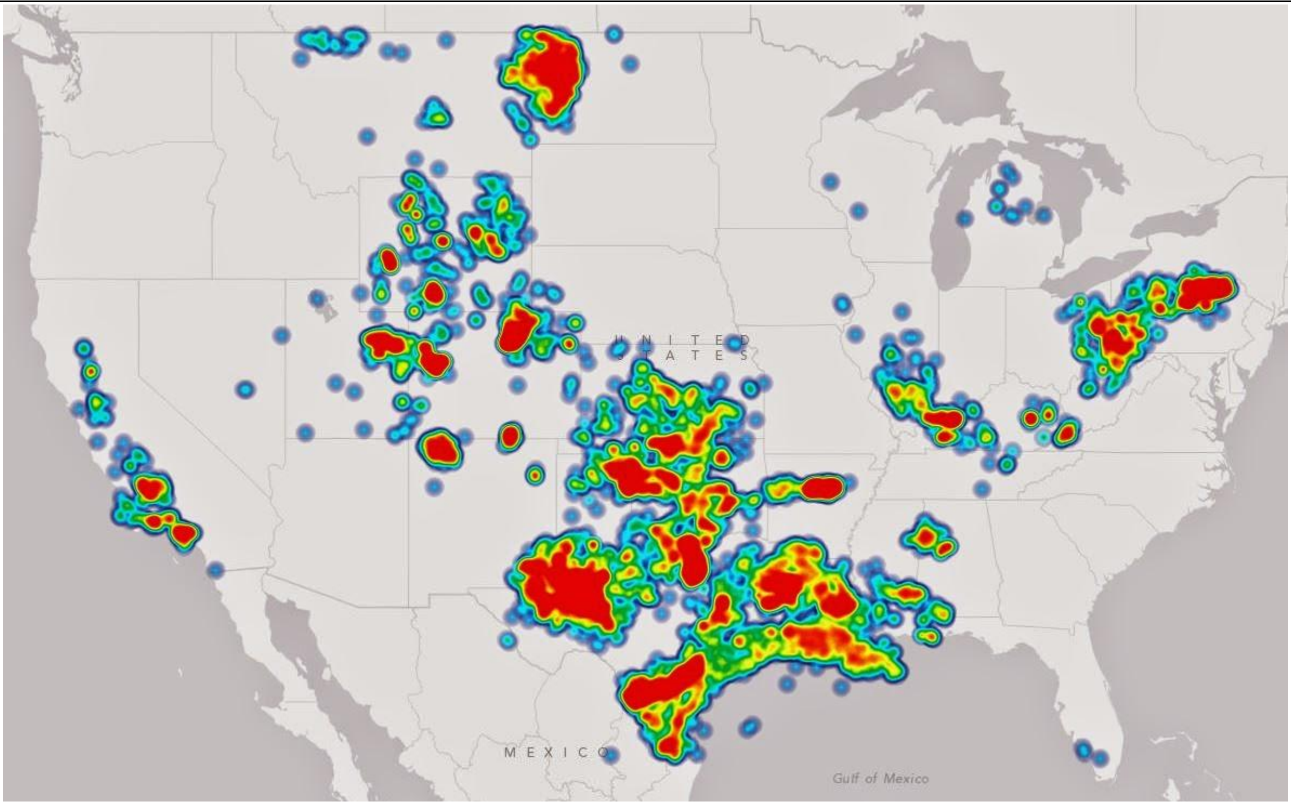

Fig. 3.2 Map of oil & natural gas drilling in the US, 2016, red and yellow colour means high and blue and green colour means lower intensities, according to ArcGIS-data from 2016[28]

3.5.22 Uzbekistan

An average distance of 2500km for pipelines from onshore sites to the Caspian Sea is estimated based on a map of current oil fields.[29]

3.7 Transport from extraction site to national regional refinery

For direct transport of crude oil from extraction site to regional refinery, the distances for on- and off-shore pipelines at origin are used (c.f. chapters 3.5 and 3.8).

3.8 Summary for the distances and means of transport

The following tables give an exemplary overview on the data which are used to model a theoretical life cycle inventory of long-distance transports of crude oil to Switzerland (Tab. 3.1), Europe (Tab. 3.2) and the global market (Tab. 3.4). Included are the shares of crude oil transported from the modelled countries of extraction (see chapter 2) and the assumed transport distances by mean of transport.

The import mixes are derived from global, regional and national statistics (EI 2024; Avenergy_Suisse 2024). As only extraction data for some of the countries were modelled, the shares of these countries (c.f. Tab. 2.1 to Tab. 2.4) are extrapolated to match 100% of the import mix

[29] https://www.eurasiansecurity.com/wp-content/uploads/2015/02/turkmenistan-oil-gas-map.jpg, online 27.02.2023

[30] Distance measured on www.maps.google.com, online 05.10.2017.

Where available and plausible, values for transport distances were kept in line with the latest studies (Jungbluth 2007; Meili et al. 2018; Stolz & Frischknecht 2017). Other distances for transport in pipelines and on open sea are taken from online maps[31,32].

Tab. 3.1 Overview of transport distances and export shares used for modelling of long-distance transports to Switzerland.

Origin of crude oil transported to CH-region	Port of Origin	Crude oil imported	Share for market mix in 2023	Distance offshore pipeline origin	Distance onshore pipeline origin	Distance destination port to refinery	Distance shipping
Source							
Reference year							
Unit		million tons	%	km	km	km	km
Algeria	Algiers	0.07	6.8%	700	600	800	800
Kazakhstan	Novorossiysk	0.02	1.8%	3'400	600	3'400	3'400
Libya	Sirtica Terminal	0.04	4.3%	200	600	1'900	1'900
Nigeria	Lagos	0.32	32.2%	140	600	7'100	7'100
United States	Houston	0.55	55.0%	1'100	600	10'100	10'100
Total		1.00	100.0%				

31 Distances for pipeline transport are taken from: www.maps.google.com, online 05.10.2017.

32 Distances for oceanic transport are taken from www.searates.com, online 05.10.2017 and https://sea-distances.org/, online 23.10.2019.

Tab. 3.2 Overview of transport distances and export shares used for modelling of long-distance transports to Europe.

Origin of crude oil transported to RER-region	Port of Origin	Crude oil imported	Share for market mix in 2021	Distance offshore pipeline origin	Distance onshore pipeline origin	Distance destination port to refinery	Distance shipping
Source							
Reference year							
Unit		million tons	%	km	km	km	km
Argentina	Buenos Aires	1.08	0.2%	20	500	100	11'800
Azerbaijan	Ceyhan (Mersin)	17.08	3.0%	200	1'800	100	6'300
Brazil	Santos	5.81	1.0%	20	800	100	10'100
Canada	Quebec	4.10	0.7%	20	3'000	100	5'900
Colombia	Tumaco	1.44	0.2%	20	800	100	9'800
Germany	Hamburg	2.38	0.4%	20	100	-	600
Algeria	Algiers	21.01	3.6%	-	700	100	-
Ecuador	Guayaquil	0.94	0.2%	20	300	100	10'100
Egypt	Alexandria	10.69	1.8%	20	100	100	-
France	Marseille	0.61	0.1%	20	100	-	3'800
United Kingdom	Southampton	31.59	5.5%	200	100	-	500
Iraq	Basrah	47.56	8.2%	-	500	100	2'900
Iran	Bahregan Sar Oilfield	0.56	0.1%	20	400	100	12'100
Italy	Trieste	3.74	0.6%	20	100	-	5'600
Kazakhstan	Novorossiysk	41.79	7.2%	20	3'400	1'400	-
Libya	Sirtica Terminal	21.54	3.7%	20	200	100	-
Mexico	Veracruz	7.65	1.3%	200	240	100	10'000
Nigeria	Lagos	51.72	8.9%	200	140	100	-
Netherlands	Rotterdam	0.86	0.1%	200	100	-	-
Norway	Bergen	72.52	12.5%	200	200	-	1'100
Poland	Gdansk	1.10	0.2%	-	100	-	1'700
Romania	Constanța	2.57	0.4%	20	100	-	6'300
Russian Federation	St. Petersburg	138.70	24.0%	-	3'800	3'700	-
Saudi Arabia	Ju' aimah	28.49	4.9%	20	1'300	100	12'000
Turkmenistan	Ceyhan (plus shipping Turkmenbashi to BAKU)	5.82	1.0%	200	2'000	100	6'600
Ukraine	Odessa	1.90	0.3%	200	100	-	6'500
United States	Houston	51.44	8.9%	20	1'100	100	9'700
Uzbekistan	Ceyhan (plus shipping Turkmenbashi to BAKU)	1.32	0.2%	-	2'500	100	6'600
Venezuela	Puerto La Cruz / Jose Petroterminal	1.24	0.2%	20	100	100	7'800
Total		575.84	100.0%				

Tab. 3.4 Overview of transport distances and export shares used for modelling of long-distance transports to the global market.

Origin of crude oil transported to GLO-region	Port of Origin	Share for market mix in 2023	Distance offshore pipeline origin	Distance onshore pipeline origin	Distance destination port to refinery	Distance shipping
Unit		%	km	km	km	km
United Arab Emirates	Dubai or Abu Dhabi	4.1%	100	100	71	7'600
Argentina	Buenos Aires	1.2%	100	500	97	15'000
Australia	Perth	0.4%	268	800	44	9'800
Azerbaijan	Ceyhan (Mersin)	0.7%	43	1'800	93	6'500
Brazil	Santos	4.3%	140	800	97	13'800
Canada	Quebec	6.5%	100	3'000	100	6'600
China	Guangdong	4.9%	100	100	36	10'200
Colombia	Tumaco	1.0%	100	800	97	11'800
Algeria	Algiers	1.4%	100	700	95	4'600
Ecuador	Guayaquil	0.6%	100	300	97	11'600
Egypt	Alexandria	0.7%	100	100	95	6'500
United Kingdom	Southampton	0.8%	166	100	93	12'200
Indonesia	Tanjung Priok	0.7%	100	100	100	15'900
India	Mumbai	0.8%	100	1'000	100	6'400
Iraq	Basrah	4.9%	-	500	92	6'400
Iran	Bahregan Sar Oilfield	5.0%	100	400	76	7'500
Kuwait	Shuaiba	3.2%	100	20	62	8'300
Kazakhstan	Novorossiysk	2.0%	100	3'400	1'254	500
Libya	Sirtica Terminal	1.4%	100	200	95	5'900
Mexico	Veracruz	2.4%	307	240	92	4'200
Malaysia	Sungai UdangPort	0.6%	100	100	100	1'200
Nigeria	Lagos	1.7%	60	140	87	10'200
Norway	Bergen	2.2%	195	200	93	12'700
Oman	Muscat	1.2%	100	100	76	6'600
Peru	Callao	0.1%	100	100	97	13'100
Qatar	Halul Island	1.7%	50	100	76	7'100
Russian Federation	St. Petersburg	12.6%	100	3'800	1'599	3'600
Saudi Arabia	Ju' aimah	12.4%	100	1'300	70	6'000
Thailand	Sriracha Oil terminals	0.3%	100	100	100	3'500
Turkmenistan	Ceyhan (plus shipping Turkmenbashi to BAKU)	0.2%	200	2'000	93	6'800
Turkey	Gemlik	0.1%	100	100	100	13'300
United States	Houston	19.2%	286	1'100	80	9'800
Venezuela	Puerto La Cruz / Jose Petroterminal	1.0%	100	100	97	11'300
Total		100.0%				

4 Evaporation Losses for storage and handling

According to information in the former study, for long-distance transport of crude oil, globally a VOC loss of 18 g/t is indicated for storage and handling (Veldt et al. 1992).

According to newer information, this value seems to be too low[33]. According to this source, in 2005, 2.4 billion tons of crude oil was moved by ship, which was roughly 62 % of all crude oil produced. From storage and loading operations roughly 3.2 billion cubic meters of air/hydrocarbon vapours (VOC) are generated per year, equivalent to 5.2 million cubic meters of liquid crude oil if recovered[33] This is equivalent to 1.4 kg/t (and not g/t) total losses. Out of this only half is VOC and the other half is inert gases. The provider of this information stated in a personal communication that the numbers are based on educated assumptions, derived from the volume of crude oil transported via sea-vessels and crude vapour pressure.

The average of former and current numbers combined with information about vapour composition is taken for the model in this study (see Tab. 4.1). Evaporation losses for storage and handling of oil products are inventoried as a lump sum independent of the transportation distance as they occur mainly during reloading and not during travel.

As these losses are less relevant in the impact assessment for long-distance transport, no further investigations are done regarding this subject.

Tab. 4.1 Composition of vapours from crude oil according to former and current source for modelling (numbers in bold)

	Veldt et al. 1992		John Zink Company		This study
	losses %weight	kg VOC/kg crude oil	losses %weight	kg VOC/kg crude oil	kg VOC/kg crude oil
Total	100.0	1.80E-05	100.0	1.38E-03	
Air/inert	-		51.7	7.11E-04	not considered
Methane	9 (0.5-25)	1.62E-06	0.1	1.38E-06	1.50E-06
Ethane	2.5 (1-6)	4.50E-07	0.2	2.75E-06	1.60E-06
Propane	16±7	2.88E-06	8.7	1.20E-04	6.13E-05
Butane	21±7	3.78E-06	18.1	2.49E-04	1.26E-04
Pentane	30±5	5.40E-06	13.5	1.86E-04	9.56E-05
Hexane	10 (5-13)	1.80E-06	7.7	1.06E-04	5.39E-05
C7 +	7.5±2	1.35E-06		0.00E+00	1.35E-06
Benzene	2.5	4.50E-07		0.00E+00	4.50E-07
Toluene	1.5	2.70E-07		0.00E+00	2.70E-07
NMVOC total		1.80E-05		6.65E-04	3.42E-04

33 John Zink Company 2013, online 17.01.2018 www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2012/pc379/presentations/d2_4_Marco_Puglisi.pdf

5 Pipeline transports

5.1 Pipeline technology and transport losses

Crude oil losses due to operational spillages in Europe have continued to decline from 3ppm in 1994 to 0.5ppm in 2015 (CONCAWE 2017; Jungbluth 2007). It is assumed, that this is a global trend. Therefore, amount of spilled crude oil and related emissions to soil and water (offshore) are updated in the datasets presented in Tab. 5.1 and Tab. 5.2. The dataset for pipeline onshore for Europe is also used to model pipelines in non-European countries. This assumption is taken because of an assumed small overall relevance and lack of specific datasets.

Tab. 5.1 Unit process raw data for transport of crude oil in an onshore pipeline

	Name	Location	InfrastructureProcess	Unit	transport, crude oil pipeline, onshore	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				RER			
	InfrastructureProcess				0			
	Unit				tkm			
product	transport, crude oil pipeline, onshore	RER	0	tkm	1.00E+0			
technosphere	electricity, medium voltage, production ENTSO, at grid	ENTSO	0	kWh	2.00E-2	1	1.53	(3,3,5,1,1,BU:1.05); Literature
	pipeline, crude oil, onshore	RER	1	km	9.46E-9	1	3.24	(3,1,5,1,1,BU:3); Literature
emission soil, industrial	Oils, unspecified	-	-	kg	2.65E-9	1	1.51	(2,1,2,1,1,BU:1.5); 0.5ppm average losses due to operational spills, times throughput of 418Mm3 divided by traffic volume of 79m3km, as reported in Concawe 2017, p. 8 and 22
	Nitrogen	-	-	kg	2.04E-12	1	1.52	(3,na,na,3,1,BU:1.5); Extrapolation for sum parameter
	Sulfur	-	-	kg	7.08E-12	1	1.52	(3,na,na,3,1,BU:1.5); Extrapolation for sum parameter

Tab. 5.2 Unit process raw data for transport of crude oil in an offshore pipeline

	Name	Location	InfrastructureProcess	Unit	transport, crude oil pipeline, offshore	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				OCE			
	InfrastructureProcess				0			
	Unit				tkm			
product	transport, crude oil pipeline, offshore	OCE	0	tkm	1.00E+0			
technosphere	diesel, burned in diesel-electric generating set	GLO	0	MJ	4.50E-1	1	1.53	(3,3,5,1,1,BU:1.05); Literature
	pipeline, crude oil, offshore	OCE	1	km	9.46E-9	1	3.23	(1,1,5,1,1,BU:3); Performance of European pipelines
emission water, ocean	Oils, unspecified	-	-	kg	2.65E-9	1	2.25	(3,3,1,3,5,BU:1.5); Literature for onshore pipelines, 0.5ppm losses due to operational spills reported in Concawe 2017
	BOD5, Biological Oxygen Demand	-	-	kg	8.33E-09	1	1.52	(3,na,na,3,1,BU:1.5); Extrapolation for sum parameter
	COD, Chemical Oxygen Demand	-	-	kg	8.33E-09	1	1.52	(3,na,na,3,1,BU:1.5); Extrapolation for sum parameter
	DOC, Dissolved Organic Carbon	-	-	kg	2.29E-09	1	1.52	(3,na,na,3,1,BU:1.5); Extrapolation for sum parameter
	TOC, Total Organic Carbon	-	-	kg	2.29E-09	1	1.52	(3,na,na,3,1,BU:1.5); Extrapolation for sum parameter
	AOX, Adsorbable Organic Halogen as Cl	-	-	kg	2.72E-14	1	2.47	(3,3,5,3,5,BU:1.5); Extrapolation for sum parameter
	Nitrogen	-	-	kg	2.04E-12	1	2.47	(3,3,5,3,5,BU:1.5); Extrapolation for sum parameter
	Sulfur	-	-	kg	7.08E-12	1	2.47	(3,3,5,3,5,BU:1.5); Extrapolation for sum parameter

5.2 Pipeline infrastructure

For the infrastructure, the formerly consulted literature information on data for pipelines in Tab. 5.3 & Tab. 5.4 , relevant for the environment (specific energy demand, emissions air and water, maintenance, energy carrier of pipeline driving systems etc.) is considered to be still valid (c.f. Jungbluth 2007).

Tab. 5.3 Unit process raw data for pipeline construction, offshore

	Name	Location	Infrastruct	Unit	*pipeline, crude oil, offshore*	Uncertaint	Standard Deviation 95%	GeneralComment
	Location				*OCE*			
	InfrastructureProcess				*1*			
	Unit				*km*			
product	pipeline, crude oil, offshore	OCE	1	km	1.00E+0			
resource, land	Transformation, from seabed, unspecified	-	-	m2	1.10E+2	1	2.29	(3,3,5,1,3,na); Calculation for gas pipeline
	Transformation, to industrial area, benthos	-	-	m2	1.10E+2	1	2.29	(3,3,5,1,3,na); Calculation for gas pipeline
	Occupation, industrial area, benthos	-	-	m2a	3.30E+3	1	1.84	(3,3,5,1,3,na); Calculation for 30a use
resource, in water	Water, unspecified natural origin, GLO	-	-	m3	1.87E+2	1	1.51	(2,3,5,1,1,na); Environmental report
technosphere	diesel, burned in building machine	GLO	0	MJ	3.34E+6	1	1.51	(2,3,5,1,1,na); Environmental report
	drawing of pipes, steel	RER	0	kg	4.00E+5	1	1.53	(3,3,5,3,1,na); Estimation
	concrete, sole plate and foundation, at plant	CH	0	m3	4.91E+1	1	1.53	(3,3,5,3,1,na); Literature
	sand, at mine	CH	0	kg	1.75E+5	1	1.53	(3,3,5,3,1,na); Literature
	steel, low-alloyed, at plant	RER	0	kg	4.00E+4	1	1.53	(3,3,5,3,1,na); Literature
	reinforcing steel, at plant	RER	0	kg	3.60E+5	1	1.53	(3,3,5,3,1,na); Literature
	aluminium, production mix, cast alloy, at plant	RER	0	kg	3.32E+3	1	10.80	(5,5,5,1,1,na); Estimation for aluminium anode, basic uncertainity estimated = 10
	cast iron, at plant	RER	0	kg	4.20E+0	1	10.80	(5,5,5,1,1,na); Estimation for aluminium anode, basic uncertainity estimated = 10
	MG-silicon, at plant	NO	0	kg	5.25E+0	1	10.80	(5,5,5,1,1,na); Estimation for aluminium anode, basic uncertainity estimated = 10
	copper, at regional storage	RER	0	kg	2.10E-1	1	10.80	(5,5,5,1,1,na); Estimation for aluminium anode, basic uncertainity estimated = 10
	zinc, primary, at regional storage	RER	0	kg	1.75E+2	1	10.80	(5,5,5,1,1,na); Estimation for aluminium anode, basic uncertainity estimated = 10
	bitumen, at refinery	RER	0	kg	9.00E+4	1	1.53	(3,3,5,3,1,na); Literature
	disposal, concrete, 5% water, to inert material landfill	CH	0	kg	1.08E+5	1	1.53	(3,3,5,3,1,na); Literature
	disposal, bitumen, 1.4% water, to sanitary landfill	CH	0	kg	9.00E+4	1	1.53	(3,3,5,3,1,na); Literature
	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	4.84E+3	1	1.51	(2,3,5,1,1,na); Environmental report
	disposal, hazardous waste, 25% water, to hazardous waste incineration	CH	0	kg	3.53E+3	1	1.51	(2,3,5,1,1,na); Environmental report
	treatment, sewage, from residence, to wastewater treatment, class 2	CH	0	m3	1.87E+2	1	1.51	(2,3,5,1,1,na); Environmental report
	transport, lorry >16t, fleet average	RER	0	tkm	7.77E+4	1	2.38	(4,5,5,5,3,na); Standard distance 100km
	transport, freight, rail	RER	0	tkm	4.01E+5	1	2.38	(4,5,5,5,3,na); Standard distance 600km
emission water, ocean	Aluminium	-	-	kg	2.82E+3	1	10.80	(5,5,5,1,1,na); Estimation 85% utilisation of anode
	Iron	-	-	kg	3.57E+0	1	10.80	(5,5,5,1,1,na); Estimation 85% utilisation of anode
	Silicon	-	-	kg	4.46E+0	1	10.80	(5,5,5,1,1,na); Estimation 85% utilisation of anode
	Copper	-	-	kg	1.79E-1	1	10.80	(5,5,5,1,1,na); Estimation 85% utilisation of anode
	Zinc	-	-	kg	1.49E+2	1	10.80	(5,5,5,1,1,na); Estimation 85% utilisation of anode
	Titanium	-	-	kg	5.99E-1	1	10.80	(5,5,5,1,1,na); Estimation 85% utilisation of anode
	weight			kg	5.12E+5			

Tab. 5.4 Unit process raw data for pipeline construction, onshore

	Name	Location	InfrastructureProcess	Unit	*pipeline, crude oil, onshore*	UncertaintyType	StandardDeviation95%	GeneralComment
	Location				*RER*			
	InfrastructureProcess				*1*			
	Unit				*km*			
product	pipeline, crude oil, onshore	RER	1	km	1.00E+0			
resource, land	Transformation, from forest, unspecified	-	-	m2	2.00E+3	1	2.52	(3,3,5,1,3,na); Calculation for gas pipeline
	Transformation, to heterogeneous, agricultural	-	-	m2	2.00E+3	1	1.89	(3,3,5,1,3,na); Calculation for gas pipeline
	Occupation, construction site	-	-	m2a	3.33E+3	1	2.08	(3,3,5,1,3,na); Occupation during construction
resource, in water	Water, unspecified natural origin, GLO	-	-	m3	8.05E+2	1	1.79	(2,3,5,1,1,na); Environmental report
technosphere	diesel, burned in building machine	GLO	0	MJ	2.60E+6	1	1.79	(2,3,5,1,1,na); Environmental report
	drawing of pipes, steel	RER	0	kg	1.40E+5	1	1.80	(3,3,5,3,1,na); Estimation
	sand, at mine	CH	0	kg	6.60E+5	1	1.80	(3,3,5,3,1,na); Literature
	steel, low-alloyed, at plant	RER	0	kg	1.50E+4	1	1.80	(3,3,5,3,1,na); Literature
	reinforcing steel, at plant	RER	0	kg	1.25E+5	1	1.80	(3,3,5,3,1,na); Literature
	disposal, municipal solid waste, 22.9% water, to municipal incineration	CH	0	kg	1.26E+3	1	1.79	(2,3,5,1,1,na); Environmental report
	disposal, hazardous waste, 25% water, to hazardous waste incineration	CH	0	kg	1.13E+3	1	1.79	(2,3,5,1,1,na); Environmental report
	treatment, sewage, from residence, to wastewater treatment, class 2	CH	0	m3	8.05E+2	1	1.79	(2,3,5,1,1,na); Environmental report
	transport, lorry >16t, fleet average	RER	0	tkm	8.00E+4	1	2.61	(4,5,5,5,3,na); Standard distance 100km
	transport, freight, rail	RER	0	tkm	4.80E+5	1	2.61	(4,5,5,5,3,na); Standard distance 600km

6 Summary of life cycle inventory data

In this chapter an exemplary life cycle inventory for the modelled and updated processes is presented. All data are provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro). The electronic data is including full EcoSpold v1 documentation. For each investigated process, two types of tables (X-Process and X-Exchange) are provided in this report. Tab. 6.1 shows the full life cycle inventory data for one of the newly modelled or updated processes. Tab. 6.5 contains Meta-information about the newly modelled and updated processes.

Tab. 6.1 Unit process raw data for produced crude oil transported to refineries in Switzerland.

CH, market	Name	Location	Category	SubCategory	InfrastructureProcess	Unit	crude oil, market mix, at long distance transport {CH} U	UncertaintyType	Standard-Deviation95%	GeneralComment
	Location						CH			
	Unit						kg			
	crude oil, market mix, at long distance transport {CH} U	CH	-	-	0	kg	1.00E+0			
	crude oil, at production {DZ} U	DZ	-	-	0	kg	6.81%	1	1.21	(1,1,1,3,3,BU:1.05); In 2023, 0.184 megatons of crude oil are imported from Algeria to Switzerland, assuming 0% offshore production. Assumed transport distances: Offshore, at origin: 100km by pipeline. Onshore, at origin: 700km by pipeline. For transport to destination: 759km by ship plus additional 600km by onshore pipeline at destination. Port of origin for shipping is assumed to be Algiers.
	crude oil, at production {KZ} U	KZ	-	-	0	kg	1.77%	1	1.21	(1,1,1,1,3,BU:1.05); In 2023, 0.048 megatons of crude oil are imported from Kazakhstan to Switzerland, assuming 12.7% offshore production. Assumed transport distances: Offshore, at origin: 100km by pipeline. Onshore, at origin: 3400km by pipeline. For transport to destination: 3397km by ship plus additional 600km by onshore pipeline at destination. Port of origin for shipping is assumed to be Novorossiysk.
	Crude oil, at production {LY} U	LY	-	-	0	kg	4.25%	1	1.21	(1,1,1,3,3,BU:1.05); In 2023, 0.115 megatons of crude oil are imported from Libya to Switzerland, assuming 20% offshore production. Assumed transport distances: Offshore, at origin: 100km by pipeline. Onshore, at origin: 200km by pipeline. For transport to destination: 1841km by ship plus additional 600km by onshore pipeline at destination. Port of origin for shipping is assumed to be Sirtica Terminal.
	crude oil, at production {NG} U	NG	-	-	0	kg	32.17%	1	1.21	(1,1,1,3,3,BU:1.05); In 2023, 0.87 megatons of crude oil are imported from Nigeria to Switzerland, assuming 90% offshore production. Assumed transport distances: Offshore, at origin: 60km by pipeline. Onshore, at origin: 140km by pipeline. For transport to destination: 7008km by ship plus additional 600km by onshore pipeline at destination. Port of origin for shipping is assumed to be Lagos.
	crude oil, at production {US} U	US	-	-	0	kg	55.03%	1	1.21	(1,1,1,1,3,BU:1.05); In 2023, 1.488 megatons of crude oil are imported from United States to Switzerland, assuming 14.6% offshore production. Assumed transport distances: Offshore, at origin: 286km by pipeline. Onshore, at origin: 1100km by pipeline. For transport to destination: 10100km by ship plus additional 600km by onshore pipeline at destination. Port of origin for shipping is assumed to be Houston.
transport	transport, transoceanic tanker {OCE} U	OCE	-	-	0	tkm	8.00E+0	1	2.06	(3,2,1,3,3,BU:2); Calculation based on estimated shipping route and pipelines according to searates.com and export data for 2023.
	transport, crude oil pipeline, offshore {OCE} U	OCE	-	-	0	tkm	4.14E-2	1	1.24	(3,2,1,3,3,BU:1.05); Calculation based on estimated shipping route and pipelines according to searates.com and export data for 2023.
	transport, crude oil pipeline, onshore {RER} U	RER	-	-	0	tkm	1.00E+0	1	1.24	(3,2,1,3,3,BU:1.05); Calculation based on estimated shipping route and pipelines according to searates.com and export data for 2023.
air, low population	Hydrocarbons, aliphatic, alkanes, unspecified	-	emissions to air	low. pop.	-	kg	1.35E-6	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling
	Benzene	-	emissions to air	low. pop.	-	kg	4.50E-7	1	3.07	(3,4,4,1,1,BU:3); Evaporation losses for storage and handling
	Butane	-	emissions to air	low. pop.	-	kg	1.26E-4	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling
	Methane, fossil	-	emissions to air	low. pop.	-	kg	1.50E-6	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling
	Ethane	-	emissions to air	low. pop.	-	kg	1.60E-6	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling
	Hexane	-	emissions to air	low. pop.	-	kg	5.39E-5	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling
	Pentane	-	emissions to air	low. pop.	-	kg	9.56E-5	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling
	Propane	-	emissions to air	low. pop.	-	kg	6.13E-5	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling
	Toluene	-	emissions to air	low. pop.	-	kg	2.70E-7	1	1.59	(3,4,4,1,1,BU:1.5); Evaporation losses for storage and handling

Tab. 6.2 Tab. 6.5 Meta information (X-Process) for one example of the investigated life cycle inventories.

ReferenceFunction	Name	crude oil, market mix, at long distance transport {CH} U
Geography	Location	CH
ReferenceFunction	InfrastructureProcess	0
ReferenceFunction	Unit	kg
	IncludedProcesses	Transportation of crude oil from exploration sites to refineries in CH-region. Includes transport service requirements and emissions from oil handling and evaporation.
	GeneralComment	Calculation for transport distances assuming transport by pipeline offshore and onshore as well as sea transport in tanker. Sites and modes of transportation based on the supply situation in 2023.
	InfrastructureIncluded	1
	Category	oil
	SubCategory	transport
TimePeriod	StartDate	2023
	EndDate	2025
	DataValidForEntirePeriod	1
	OtherPeriodText	Transport modes investigated for 2023.
Geography	Text	Calculations include production and transport of crude oil from 5 countries.
Technology	Text	Operation of crude oil pipelines by electricity.
	ProductionVolume	2.7 million tons of directly imported crude oil to CH region in 2023.
	SamplingProcedure	Literature. Online calculators for distances. The consumption mix is calculated based on international trade statistics for 2023.
	Extrapolations	none
	UncertaintyAdjustments	none
ecoinvent v3	ProductionVolumeNumber	2.7
	ProductionVolumeText	Megatons of oil transported in 2023

7 Outlook

Due to the availability of more specific national data on flaring of associated petroleum gas (APG) and unintentional methane emissions during oil production, and its high relevance for the country-specific environmental impacts of crude oil extraction, the composition of the crude oil import mix has a higher importance.

Therefore, it is recommended to update the LCI for the crude oil import mix regularly to monitor the environmental impacts related to crude oil supply in different markets.

Some feedback to the present models indicated that data for shipping of crude oil and especially associated sulphur dioxide emissions might be outdated and not reflecting implementation of the IMO 2020 reduction in maximum sulphur content for marine fuel. Controlling this was out of the scope of this project. Such an update would be recommended, based on literature (e.g. Rajabi et al. 2020). It might also be part of a general update project for transport processes of sea transports.

The LCI is built up for different life cycle stages. It would be recommended to do an assessment and interpretation of the global warming potential for the full chain, in order to better understand possible deviations from data sources like the analysis in the world energy outlook 2018 (IEA 2018, page 486ff).

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