2021 UPDATE TO

THE EUROBITUME LIFE-CYCLE INVENTORY FOR BITUMEN

VERSION 3.1

eurobitume

INDEX

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1. INTRODUCTION

Following the previous life-cycle inventory (LCI) published in 2020, Eurobitume has now updated some activity and the background data used for this cradle-to-gate study. The LCI covers four of the life-cycle stages;

- Crude oil extraction;
- Transportation;
- Refining;
- Storage within the refinery.

The study covers the production of 1 tonne of straight–run bitumen manufactured by atmospheric and vacuum distillation.

The primary data sources were chosen on the basis that they were publicly available and from a reputable source. However, the foreground data were supplemented by background data from ecoinvent (version 3.6) where complete datasets were not available.

A full life-cycle inventory is available in an Excel format for use in LCA (Life-Cycle Assessment) software. This report provides summary data for the four life-cycle stages with and without infrastructure contributions.

As the 2020 LCI, this supplementary 2021 update has been conducted in accordance with ISO 14040 and ISO 14044.

Compared to the 2020 LCI, this 2021 LCI update contains the following updates:

- The latest published IOGP (International Oil & Gas Producers' Association) data (2018 and 2019) for emissions in the crude oil extraction step;
- IMO 2020 regulation concerning sulphur content in fuel oil used onboard ships operating outside designated emission control areas is reduced to 0,50% m/m (mass by mass);
- Energy consumption at the refinery step has been corrected;
- The background data has been updated from ecoinvent 3.5 to ecoinvent 3.6.

Additionally, this update contains the life-cycle impact assessment of the EN 15804:2012+A1:2013 and EN 15804:2012+A2:2019+AC:2021 [1] environmental impact indicators in the appendices. The LCI update has not been subject to an additional independent review, as no changes have been made to the methodology, only to the data.

This report outlines the activity data changes compared to the 2020 LCI and provides the corresponding LCI and LCIA results. A brief comparison between the 2020 and 2021 LCI and LCIA results is provided in the appendices.

For some sections, the relationship to the 2020 Eurobitume LCI Report is explicitly stated.

This supplementary update should only be used together with the 2020 LCI report.

2. UPDATES TO THE ACTIVITY DATA

2.1 Update to the crude oil extraction data

(Update related to section 5.2 of the 2020 Eurobitume LCI Report)

Crude oil extraction data is based on the IOGP data, completed with ecoinvent 3.6 datasets for background processes. Data for crude oil extraction are averaged over the years 2015 – 2019 using data derived from the IOGP Environmental Performance Indicators reports [2], the most recent being 2019 and previous volumes of the same report. Mean values of the reported data for the years 2013 – 2017 were selected for the 2020 LCI report, and the years 2015 – 2019 were selected for this update. These data represent oil and gas wellhead production of 2,184 million tonnes (15,4 billion BOE*), about 28% of 2019 global production sales [3], with the absolute and relative production values at similar levels in previous years to 2010. Regional coverage is uneven, ranging from 79% of known production in Europe to 11% in the Former Soviet Union (FSU). The data are considered to be representative of IOGP membership production. In discussion with IOGP, the data for the Russian Federation are the less robust data. This is due to a lack of reporting from Russian oil and gas producers. However, despite this, data are provided by IOGP member companies that have Joint Venture relationships in the Russian Federation. Much of the IOGP data are independently verified so confidence in the data is considered to be adequate for the aggregated data used in this study, but the uncertainties suggest that such data should not be used for individual refineries, or specific crude oils.

IOGP data include the following operations:

- Drilling (exploration, appraisal and production drilling);
- Oil and gas extraction and separation (primary production);
- Primary oil processing (water separation, stabilisation);
- Crude oil transportation by pipeline to storage facilities;
- Offshore crude oil ship loading from primary production;
- Onshore crude oil storage connected by pipeline to primary production facilities;
- Gas transportation to processing plant (offshore/onshore);
- Primary gas processing (dehydration, liquids separation, sweetening, CO_2 removal) performed with the intent of making the produced gas meet sales specifications;
- Floating Storage Units (FSUs);
- Offshore support and standby vessels;
- Exploration (including seismic) activities;
- Activities related to geologic storage of CO_2 from natural gas processing;
- Mining activities related to the extraction of hydrocarbons.

The following items are specifically excluded by IOGP:

- Gas processing activities with the primary intent of producing gas liquids for sale (unless data cannot be separated out):
  - Secondary liquid separation (i.e. Natural Gas Liquids [NGL] extraction using refrigeration processing);
  - Ethane, Propane, Butane, Condensate (EPBC) fractionation;
  - Liquefied Natural Gas (LNG) and Gas to Liquids (GTL) operations (LNG data are being compiled separately from the E&P data using this same process);
- Transportation of personnel;
- Transportation of oil and gas, after sales metering devices (LACT units) or after ship loading at the primary production site;
- Storage of refined products;
- Partners' operations;
- Non-operated joint ventures, except when the operator is not an IOGP member and the joint venture has agreed that one company should take the lead on data reporting;
- Upgrading activities related to the extraction of hydrocarbons. All other non-E&P activities.

It should be noted that the crude basket in this update is unchanged from the 2020 LCI. The following table shows the crude oil basket used in the LCI, compared to the average European crude oil consumption in 2019 [4].

Table 1. Crude basket used for the LCI review in 2020 and 2021 update

Crude source	2021 LCI (%) – used in this study (same values as 2020 LCI)	Average European crude oil consumption (2019)
Former Soviet Union (FSU)	30%	36%
South & Central America	15%	3,65%**
Middle East	45%	16,5%
Europe	10%	15%
Africa	0%	21%
North America	0%	7,85%
Total	**100%**	**100%**

Raw material energy use and emission data were derived from the IOGP environmental reports, providing data between 2003 and 2019. Mean values of the reported data for the years 2013 – 2017 were selected for the 2020 LCI report, and the years 2015 – 2019 were selected for this update. Figure 1 illustrates the variability in annual emission data for CO_2 equivalent (CO_2eq or CO_2e) on a regional basis.

* Barrels of Oil Equivalent

** Percentage of crude oil from south, central and north America

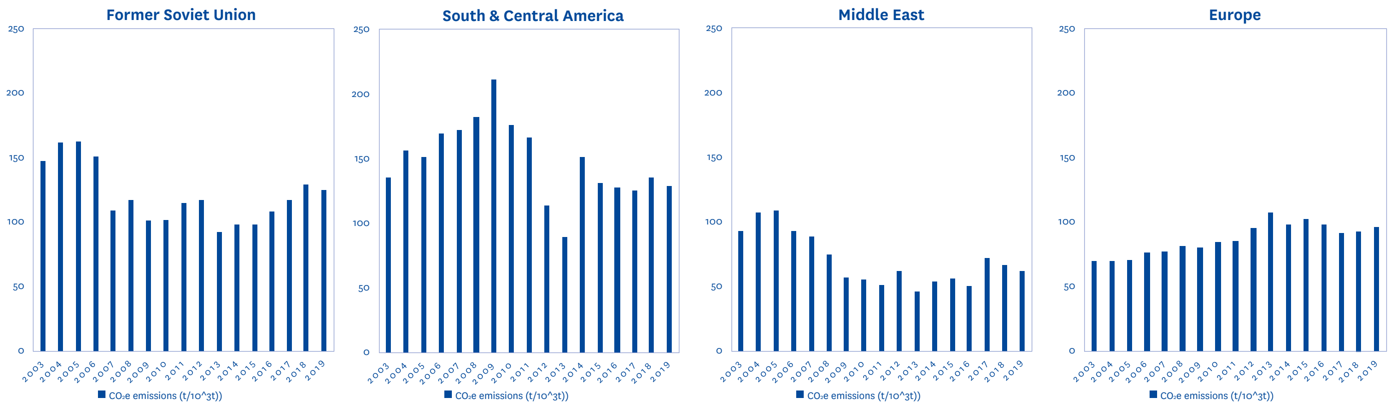

Figure 1. CO_2eq emissions for crude oil extraction, by region over time

The aggregated CO_2 eq emission data for crude oil extraction compared to the data used in the previous reports and for 2015 – 2019 are shown in Figure 2.

Data available from IOGP for crude oil extraction have been published since 1999, the criteria for the data collection are transparent and consistent. Therefore, the main flows provided by IOGP were included into ecoinvent datasets. These flows were also completed by considering indirect emissions, from energy and material purchase. To be noted that IOGP data are used in conjunction with other sources in commercial LCI databases but were also considered in the study from Meili et al. on life-cycle inventories of crude oil extraction [5].

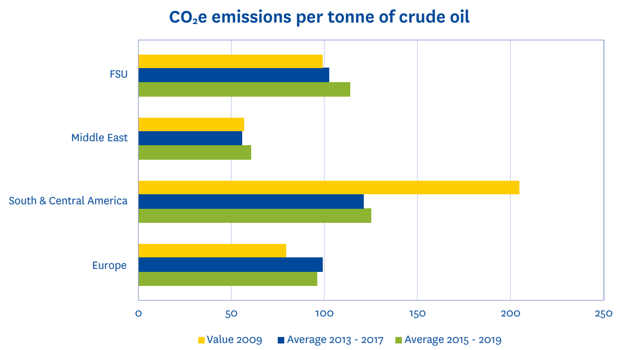

Figure 2. Comparison of 2009 Crude oil extraction data with values for 2013–2017 and 2015–2019 (source IOGP)

IOGP reports a range of environmental endpoints and for this study the following inputs and outputs were selected:

- Total energy consumption per unit of production;
- Carbon dioxide (CO_2) emissions;
- Methane (CH_4) emissions;
- Greenhouse Gas (GHG) emissions (CO_2e);
- Non-Methane Volatile Organic Compound (NMVOC) emissions;
- Sulphur dioxide (SO_2) emissions;
- Nitrogen oxide (NO_X) emissions;
- Emissions to water;
- Emissions to soil;

2.1.1 Data quality: note on the temporal, geographical & technological representativeness

The selection of data sources was conducted on the basis of the identification of the most appropriate source of data for current production of bitumen in Europe in 2020. The Task Force conducted literature surveys to identify the most recent and relevant reports from which the data were available.

- The data for the principal processes is representative of the European context. The crude oil basket, whilst not necessarily applicable for any individual refinery, is believed to be representative of the average European supply for bitumen manufacture and has been reviewed by Concawe, the European oil refining association. Transportation is representative of the principal routes to Europe from the regions of crude oil extraction.
- Data for crude oil extraction (in 2019) represent 42 of IOGP's 56 members operating companies covering operations in 72 countries worldwide and ~28% of global production sales. In this report data are provided as an average of 5 years (2015 – 2019). A review of extraction data over several years indicated that energy consumption and emissions can change significantly from one year to the next, due to differences in reporting and/or due to actual changes in energy/emissions, therefore an average value over 5 years was considered to be the most representative approach.
- Shipping data are taken from technical data sheets of a major ship constructor [6] and transportation distances are derived from a publicly available shipping rate calculator [7].
- Refinery fuel consumptions and emissions data are taken from Concawe [8], whose members include 41 companies that operate petroleum refineries in the European Economic Area. Data for emissions and fuel consumption represent 44 refineries and 52% of European refinery throughput.

Other process data from the ecoinvent 3.6 database is representative of the current average technology in Europe.

2.1.2 Crude oil extraction data

Table 2. Summary data for crude oil extraction

	Unit	Former Soviet Union	Middle East	South America	Europe	Total
Crude oil source	%	30	45	15	10	100
Raw material						
Crude oil	kg/t	1 000	1 000	1 000	1 000	1 000
Fresh water	L/t	132	4	84	39	58
Consumption of energy resources						
Process						
Crude oil - onsite combustion	kg/t	0	0	13,5	0	2,0
Natural gas - onsite combustion	kg/t	26	6	12	27	15
Purchased electricity	kWh/t	15	29	9	26	22
Losses						
Natural gas, flared	kg/t	6,6	4,3	6,8	3,8	5,3
Natural gas, vented	kg/t	0,74	0,10	0,60	0,37	0,39
Emissions to air						
CO_2	g/t	106 996	82 347	117 837	98 738	96 704
CO [1)]	g/t	10	12	8	10	10
SO_2	g/t	237	695	207	60	421
NO_X	g/t	227	191	508	329	264
CH_4	g/t	778	135	638	396	430
NMVOC	g/t	105	260	877	232	303
Particulates [1)]	g/t	28	9	5	18	15
Emissions to water						
Oil	g/t	0,6	10,3	17,5	44,9	11,9
Emissions to soil						
Oil spills	g/t	3,5	11,8	4,2	3,1	7,3

1) From ecoinvent v3.6 background data

2.2 Update to ship fuel oil sulphur content

(Update related to section 5.3 of the 2020 LCI)

The crude oils for European bitumen production are mainly transported to the refinery by ship. The exception is Former Soviet Union crude oil, that is partly transported by pipeline. In this study it is assumed that the FSU crude oil is transported from the Samara area to the Baltic Sea by the Baltic Pipeline System (BPS) and then, from the Baltic Sea to the ARA region by ship.

2.2.1 Transport by ship

(Update related to section 5.4.1 of the 2020 LCI)

In the calculations, crude oil is transported to Europe in 106 000 Dead Weight Tonne (DWT) Aframax* vessels. This is a typical vessel size for Former Soviet Union and South America. For Middle East crude oil using the route via Suez, the size varies between 130 000 DWT and 250 000 DWT, and for Europe the size is 70 000 DWT. The use of a 106 000 DWT ship for all regions is considered to be a conservative compromise. Data are summarised in Table 3. The inventory “Transport, freight, sea, transoceanic tanker {GLO}| processing” from ecoinvent v3.6 was adapted with more up-to-date and specific data.

2.2.1.1 Emissions to air

Emission factors for ship fuel combustion were taken from the IMO GHG4 report [9], using data for slow-speed diesel, 2-stroke diesel engines compliant with IMO Tier II criteria. These data are considered to provide a conservative estimate of emissions, as the ship for which the data are provided is fitted with emission reduction technology, compliant with IMO Tier III criteria, which would reduce SO_X and NO_X emissions. Compliance with Tier III would reduce NO_X emissions by a factor of approximately 4.

SO_2 emissions are calculated on the basis of 0,5% sulphur fuel oil being used outside the Sulphur Oxide Emission Control (SECA) area and 0,1% sulphur fuel oil within the SECA area. Data from Marintek [10] reported that there are no methane emissions from diesel engines running Medium or Heavy Fuel Oil, therefore no methane emissions are attributed to shipping fuel combustion.

The value for sulphur content has been reduced to 0,5% in 2020, which has had a concomitant impact on emissions of sulphur oxides since that time. Within the SECA of Europe the maximum content of sulphur in fuel oil is 0,1%, this figure is used for shipping fuel combustion in SECA waters. A comparison with ecoinvent dataset can be found in Appendix 2.

* Average Freight Rate Assessment (AFRA) denomination for oil tankers

Table 3. Ship transportation data

Crude oil source	Unit	Former Soviet Union	Middle East	South America	Europe	Total
	%	30	45	15	10	100
Sea transport to ARA from		St, Petersburg Russia [1)]	Ras Tanura Saudi Arabia [2)]	Maracaibo Venezuela	Bergen North Sea	
Data on sea transport						
Vessel	DWT (t)	106 000	106 000	106 000	106 000	106 000
Distance	km	2 332	12 040	8 253	1 007	7 456
Speed	km/h	25	25	25	25	
Duration	h	93	482	330	40	298
Fuel consumption, total	t/trip	253	1 252	862	117	780
- Fuel 2,7% S	t/trip		1 164	781		641
- Fuel 1,0% S	t/trip				59	5,9
- Fuel 0,1% S	t/trip	253	88	81	59	133
Consumption of energy resources						
Heavy fuel oil	kg/t	2,39	11,81	8,13	1,10	7,36

1) Around Denmark, not via the Kiel Canal

2) Via Suez

The data for infrastructure is described in Appendix 1.

2.3 Correction to the energy consumption in the refinery step

The straight-run distillation process is shown in Figure 3. In this process, the residue from the atmospheric distillation of crude oil is further distilled in a vacuum tower to produce paving grade bitumen.

In a complex refinery a broad range of petroleum products is produced, bitumen being a minor product compared with other products.

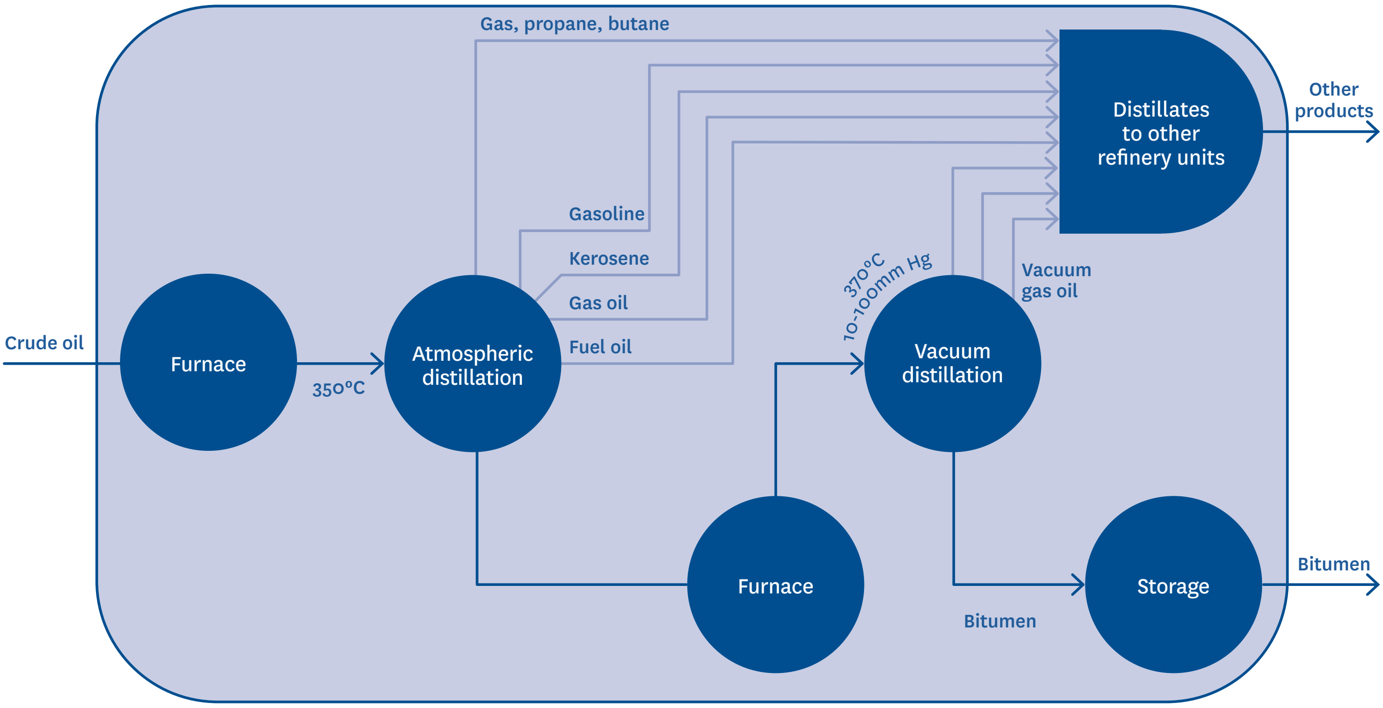

Figure 3. Schematic diagram of the refinery process

The bitumen yield from the average European bitumen crude blend is 28.5% by mass.

The process unit emission values include a share of common resources such as crude oil handling, desalting, flaring, loading area, general heating and lighting. No chemicals are added to paving grade bitumen or to the straight-run distillation process.

The data concerning refinery infrastructure are presented in Appendix 1.

2.3.1 Bitumen production: Consumption of energy resources

The allocation of energy and emissions at the refining level is complex due to the numerous coproducts produced during the distillation process. The thermodynamic allocation methodology is unchanged from the 2020 LCI.

The energy mix used for the calculations was based upon data from Concawe from a survey conducted in 2015 [5]. 96,4% of the total energy (steam, heat and internal electricity) needed for the production is produced in the refinery from refinery gas (83,1%) and heavy fuel oil (13,3%), the remaining 3,6% is assumed (by Concawe) to be gaseous fuel, such as natural gas. All gaseous fuel were considered equivalent to refinery gas (same calorific value and life-cycle inventory).

Table 4. Distribution of energy sources for bitumen production in refinery (related to Table 9 in 2020 LCI)

Distribution of energy sources for bitumen production in refinery	%	MJ/t bitumen
Heavy fuel oil	13,3%	41,9
Refinery gas	83,1%	261,8
Natural gas	3,6%	11,3
Total	**100%**	**315**

The calorific values of the heavy fuel oil (40,0 MJ/kg) and refinery gas (49,4 MJ/kg) allow the calculation of the consumption of energy for the production of bitumen by straight-run distillation. The following amount of heavy fuel oil and refinery gas (including natural gas) were considered:

Table 5. Energy consumption for bitumen production in refinery (related to Table 10 in 2020 LCI)

Heavy fuel oil	1,05 kg/t bitumen
Refinery gas	5,30 kg/t bitumen
Natural gas	0,23 kg/t bitumen

The consumptions and emissions due to the production and consumption of refinery gas and heavy fuel oil are given in the following life-cycle inventories of the ecoinvent 3.6 database: "Heat, district or industrial, other than natural gas {Europe without Switzerland}| refinery gas, burned in furnace | Cut-off,U" and "Heavy fuel oil, burned in refinery furnace {Europe without Switzerland}| processing | Cut-off, U".

2.3.2 Bitumen storage: Consumption of energy resources

(Update related to section 5.5.1 of the 2020 LCI)

The mean energy losses from the storage tanks and pipework were calculated by three independent sources using standard engineering methodology and calculations. The average energy use was as follows:

- Maintain the bitumen temperature within the storage tank 70,1 MJ/t
- Maintain the temperature within the pipework 20,2 MJ/t
- Circulate and load bitumen 9,7 MJ/t
- Total storage energy 100 MJ/t

Table 6. Energy calculations for bitumen storage

Bitumen tank			Heat losses		
Volume	m³	6 200	**Bitumen storage**	MJ/t	**70,1**
Temperature	°C	175	**Pipelines**		
Annual throughput	t	40 000	- bitumen	MJ/t	**20,2**
Outside conditions			- heating oil	MJ/t	
Temperature	°C	10	**Total storage**	MJ/t	**90,3**
Wind	m/s	5	**Energy need**	MJ/t	**90,3**
Annual use	h	8 000	Fuel for Hot oil		
Heating oil effiency	%	85	**Energy need**	MJ/t	**9,7**
Pumps	kW	11	Electricity		
Annual usage time	h	8 760	**Total energy**	**MJ/t**	**100,0**

Refinery fuels are used in heating the tank and pipe work. The split between refinery gas and heavy fuel oil is the same as in the refinery. The circulation and loading pump utilises electricity from the grid.

Table 7. Energy source at refinery for bitumen storage

Energy source	Split %	Energy MJ/t	Fuel kg/t bitumen	Energy kWh/t bitumen
Refinery gas	86,7	78,3	1,58	
Heavy fuel oil	13,3	12,0	0,30	
Electricity	-	9,7		2,69

The consumptions and emissions due to the production of electricity and to the production and combustion of heavy fuel oil and refinery gas are calculated in the same way as in the refining step.

3. SUMMARY DATA (CUMULATIVE LCI RESULTS)

(Update related to section 6 of the 2020 LCI)

The summary of the life-cycle inventory for the production of 1 tonne of bitumen is presented in Table 8. The table presents the most relevant flows and an aggregation of other flows. A complete inventory in a SimaPro csv format is available from Eurobitume on request: info@eurobitume.eu

In this LCI update it is important to note that that crude oil is used in different ways:

- As an energy source that is consumed when extracting, transporting and refining of crude oil;
- As a raw material to produce bitumen, which is the heaviest fraction of crude oil. This part of the crude oil is not an energy use. However, in the context of EN 158043 this use would comprise a "non-renewable energy source used as material".

It should be noted that the data was used as input data to construct the bitumen model in SimaPro. The background database used for the model was ecoinvent v3.6. From this model, LCIs of elementary flows were obtained directly as output from SimaPro. The following tables show the results of these LCIs restrained to the elementary flows of interest for the study (the full LCIs in the SimaPro CSV format) are available from Eurobitume on request (see above). It is important to highlight that the LCI update final flows include both the input activity data as well as the background data, which is why the activity data tables and the LCI tables are not directly comparable.

Additionally, regarding energy resource consumption it should be noted that the ecoinvent dataset "Heat, district or industrial, other than natural gas {Europe without Switzerland}| refinery gas, burned in furnace | Cut-off, U" was used for the consumption and combustion of refinery gas during the refining of bitumen. In this dataset, there is a methodological choice where refinery gas is considered a "burden free" co-product of the refinery, hence there is no elementary flow for the consumption of refinery gas. This is why the value for natural gas consumption in tables 8 and 9 may seem "low" compared to the input data in Table 7. However, the dataset does account for all emissions arising from the combustion of refinery gas.

The table below presents the life-cycle inventory for the process. A brief comparison between the 2020 LCI and the 2021 update is provided on a selection of elementary flows in Appendix 3.

Table 8. Summary life-cycle inventory for the production of 1 tonne of bitumen – without infrastructure

Production of 1 tonne of bitumen (process without infrastructure)	Unit	Crude oil extraction	Transport	Refinery	Storage	Total
Raw material						
Crude oil	kg	1 000				1 000
Consumption of energy resources						
Natural gas	kg	24,1	0,252	0,238	0,099	24,6
Crude oil	kg	3,66	7,66	7,66	0,31	19,3
Consumption of non-energy resources						
Water[1]	L	111	21,5	223	5,5	376
Emissions to air						
CO_2	g	96 704	20 606	21 356	6 354	145 020
SO_2	g	421	82,2	67,2	15,7	586
NO_X	g	264	604	28,3	7,13	903
CO	g	10,5	39,1	7,82	1,88	59,3
CH_4	g	430	8,98	10,1	2,27	451
NMVOC	g	303	30,9	9,65	0,82	345
Particulates	g	14,8	58,3	6,56	2,53	82,2
Emissions to water						
Chemical Oxygen Demand	g	18 987	2 209	102	3,23	21 301
Biological Oxygen Demand	g	18 969	2 208	78,6	3,06	21 259
Suspended solids	g	71,2	0,54	6,78	0,21	78,8
Hydrocarbon (crude oil)	g	11,9	23,9	24,1	0,94	60,8
Emissions to soil						
Hydrocarbon (crude oil)	g	7,3	31,6	25,8	1,03	65,8

1) Excluding water cooling and turbine use

2) Excluding raw material

Table 9. Summary life-cycle inventory for the production of 1 tonne of bitumen – with infrastructure

Production of 1 tonne of bitumen (process with infrastructure)	Unit	Crude oil extraction	Transport	Refinery	Storage	Total
Raw material						
Crude oil	kg	1 000				1 000
Consumption of energy resources						
Natural gas	kg	25,5	0,95	0,27	0,10	26,8
Crude oil	kg	10,8	8,35	7,72	0,31	27,1
Consumption of non-energy resources						
Water[1]	L	836	85,2	231	5,94	1159
Emissions to air						
CO_2	g	135 682	32 110	22 147	6 391	196 331
SO_2	g	507	113	70,7	15,9	706
NO_X	g	562	645	31,6	7,33	1 245
CO	g	383	95,0	15,9	2,14	496
CH_4	g	538	39,6	12,4	2,37	592
NMVOC	g	389	40,5	10,8	0,88	441
Particulates	g	157	102	10,4	2,69	272
Emissions to water						
Chemical Oxygen Demand	g	19 312	2 243	106	3,48	21 664
Biological Oxygen Demand	g	19 111	2 225	80,4	3,16	21 419
Suspended solids	g	286	36,1	10,25	0,460	332
Hydrocarbon (crude oil)	g	33,3	26,6	24,3	0,96	85,1
Emissions to soil						
Hydrocarbon (crude oil)	g	29,5	33,9	26,0	1,04	90,5

1) Excluding water cooling and turbine use

2) Excluding raw material

It should be noted that natural gas consumption at the refinery step was 0,037 kg/t in the 2020 LCI whereas it is now 0,238 kg/t (without infrastructures) in this 2021 update. This significant difference can be attributed to the update in the dataset "Heat, district or industrial, other than natural gas {Europe without Switzerland}| refinery gas, burned in furnace | Cut-off, U." Indeed, in ecoinvent 3.5 this dataset only included the air emissions from the combustion of refinery gas (the reason might be that the natural gas was considered as a co-product of the refinery and hence "burden-free"). In ecoinvent 3.6 the dataset also includes the impacts from the production of refinery gas itself.

4. LIFE-CYCLE IMPACT ASSESSMENT

(Update related to section 7 of the 2020 LCI)

A general functional unit cannot be given to application-unspecific materials such as bitumen, hence the following declared unit (DU) was assessed: **1 tonne (1000 kg) of paving grade bitumen**. The same system boundaries as presented in the introduction were considered.

The set of environmental impact categories considered are the impact categories considered relevant for the LCI. The following table summarizes the environmental indicators considered for this LCIA:

Table 10. Environmental impact categories and indicators assessed and analysed

Impact category	Impact indicator	Characterisation method - model	Unit
Climate Change	Global warming potential	IPCC 2013 (AR5), Baseline model of 100 yrs (IPCC, 2013) IPCC 2007 (AR5), Baseline model of 100 yrs (IPCC, 2007)	kg CO_2 eq
Ozone Depletion	Ozone Depletion Potential (ODP)	Steady-state ODPs as in (WMO 1999)	kg CFC-11 eq
Acidification	Accumulated Exceedance (AE)	Seppala 2006	mol H+ eq
Resource use, energy carriers	Abiotic Resource Depletion – fossil fuels (ADP-fossil)	CML v4.8 (2016) based on van Oers et al. (2002)	MJ
Photochemical Ozone Formation	Photochemical Ozone Creation Potential (POCP)	LOTOS-EUROS (Van Zelm et al, 2008) as applied in the EF Method adapted by Pré	kg NMVOC eq

A brief comparison between the 2020 LCIA results and the 2021 update is provided in Appendix 3. Additionally, in this update all the characterised results for the environmental impact categories in EN 15804+A1 and EN 15804+A2 are provided in Appendix 4. The following tables and figures provide the results for the DU per life-cycle steps:

Table 11. Potential environmental impact for the production of 1 tonne of paving grade bitumen – without infrastructure

Impact category	Unit	Crude oil production	Transportation	Refining step	Storage	Total
Climate Change - IPCC 2013	kg CO_2 eq	110	21,1	21,7	6,45	160
Climate Change - IPCC 2007	kg CO_2 eq	108	21,1	21,6	6,47	157
Ozone Depletion	kg CFC_{11} eq	2,93E-06	5,63E-06	5,62E-06	3,04E-07	1,45E-05
Acidification	mol H+ eq	0,748	0,567	0,109	0,03	1,45
Resource use, energy carriers	MJ	44488	345	342	35,2	45210
Photochemical Ozone Formation	kg NMVOC eq	0,61	0,64	0,04	0,01	1,31

Table 12. Potential environmental impact for the production of 1 tonne of paving grade bitumen – with infrastructure

Impact category	Unit	Crude oil production	Transportation	Refining step	Storage	Total
Climate change - IPCC 2013	kg CO_2 eq	153	33,8	22,6	6,49	216
Climate change - IPCC 2007	kg CO_2 eq	151	33,6	22,5	6,51	213
Ozone depletion	kg CFC-11 eq	8,43E-06	6,48E-06	5,69E-06	3,08E-07	2,09E-05
Acidification	mol H^+ eq	1,09	0,638	0,116	0,0266	1,87
Resource use, energy carriers	MJ	45034	512	353	35,7	45934
Photochemical Ozone Formation	kg NMVOC eq	1,02	0,700	0,0492	9,65E-03	1,78

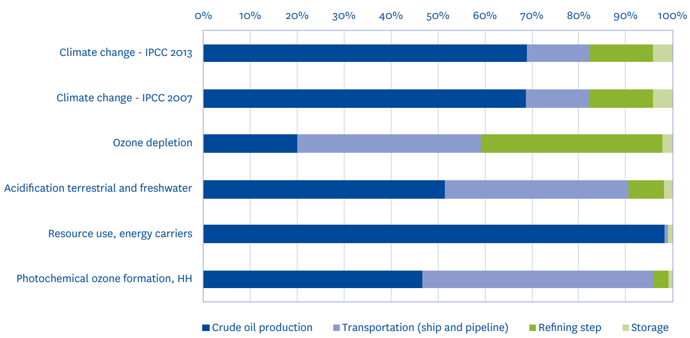

Figure 4. Breakdown of potential environmental impacts on the main life-cycle steps - Results for 1 declared unit, without infrastructure

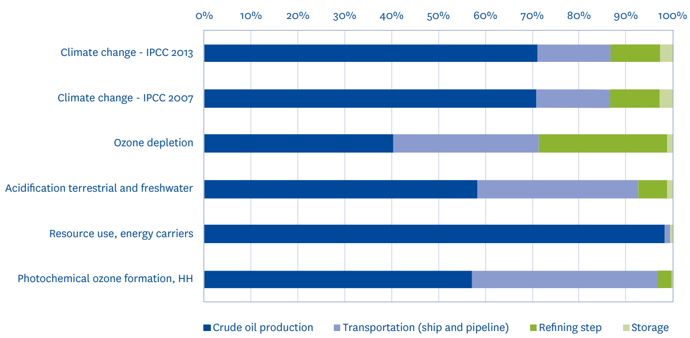

Figure 5. Breakdown of potential environmental impacts on the main life-cycle steps - Results for 1 declared unit, with infrastructure

The following observations can be made for the results without infrastructure:

- The crude oil production is the main contributor to the climate change, acidification and resource use, energy carriers impacts, with a contribution up to 99% of the resource use, energy carriers impact (which is due to crude oil itself). Furthermore, it is the second most important contributor to the photochemical ozone formation impact.
- The transportation step also has a significant contribution, especially for the photochemical ozone formation category. This is mainly related to the consumption of heavy fuel oil for the sea transportation by ship.
- The refining and storage steps have a lower contribution: around 14% for climate change and less than 8% for the other categories for the refining step, and less the 5% of all impact categories for the storage step. The 39% contribution to ozone depletion for the refining step can be attributed to the background Halon 1301 emissions from the offshore production of petroleum, due to the consumption and production of refinery gas.

Infrastructure has a big impact on the results, leading to an increase of 36% of the climate change impact and 44% on the ozone depletion impact. This is driven by the production of onshore wells and diesel consumption at wells for their construction.

5. UNCERTAINTIES

(Update related to section 8 of the 2020 LCI)

The uncertainties of the LCI were calculated via Monte Carlo simulations, based on the uncertainty assessment done via the Pedigree Matrix. The scores for the Pedigree Matrix are shown in Appendix 3 of the 2020 LCI. Lognormal distribution has been used for all values.
However, this approach is only applied to the foreground data, and it does not consider the uncertainty linked to missing or wrong information and improper background datasets. The following tables give the uncertainty parameters for the five impact categories studied in this report for the results with and without infrastructure with a confidence interval of 95%.

Table 13. Uncertainty results for a confidence interval of 95% - without infrastructure

Impact category	Unit	Mean	Median	Standard deviation	Coefficient of variation	2,50%	97,50%	Standard Error of the Mean
Climate change - IPCC 2013	kg CO_2 eq	159,9	159,7	5,0	3,1	150,9	170,6	0,16
Climate change - IPCC 2007	kg CO_2 eq	157,7	157,5	4,8	3,1	149,0	168,1	0,15
Ozone depletion	kg CFC-11 eq	1,47E-05	1,35E-05	5,54E-06	3,76E+01	7,93E-06	2,96E-05	1,75E-07
Acidification terrestrial and freshwater	mol H^+ eq	1,47	1,44	0,23	15,87	1,06	1,99	7,35E-03
Resource use, energy carriers	MJ	45268	45043	3924	8,7	38296	53934	124,1
Photochemical ozone formation	kg NMVOC eq	1,31	1,30	0,13	9,66	1,08	1,59	3,99E-03

Table 14. Uncertainty results for a confidence interval of 95% - with infrastructure

Impact category	Unit	Mean	Median	Standard deviation	Coefficient of variation	2,50%	97,50%	Standard Error of the Mean
Climate change - IPCC 2013	kg CO_2 eq	216,1	211,5	23,6	10,9	189,3	273,1	0,75
Climate change - IPCC 2007	kg CO_2 eq	213,2	208,7	23,5	11,0	187,0	268,5	0,74
Ozone depletion	kg CFC-11 eq	2,12E-05	1,89E-05	1,10E-05	5,16E+01	1,05E-05	4,42E-05	3,47E-07
Acidification terrestrial and freshwater	mol H^+ eq	1,85	1,78	0,38	20,63	1,37	2,66	1,21E-02
Resource use, energy carriers	MJ	46005	45637	4078	8,9	39170	54623	129,0
Photochemical ozone formation	kg NMVOC eq	1,76	1,68	0,42	23,63	1,39	2,76	1,32E-02

6. USE OF THE LIFE-CYCLE INVENTORY DATA

(Update related to section 8 of the 2020 LCI)

A life-cycle inventory is a phase of the life-cycle assessment involving the compilation of inputs and outputs for a product throughout its life-cycle. An environmental impact assessment is conducted on the basis of the inventory flows. Different methods can be used to deal with impact assessment. These methodologies mainly deal with impacts on "Human health", "Ecosystem quality", "Climate change" and "Resource depletion" and they differ in the definition, calculation and aggregation of impacts.

Bitumen is almost never used on its own, but is generally a raw material used in the manufacture of construction products. In the context of EN 15804 this LCI is intended to provide data for Type III environmental product declarations (EPD) for stage A1 (raw material supply) of the product life-cycle.

The data provided in this LCI are based around publicly available average data from sources that Eurobitume believes are reliable and representative for bitumen production at the gate of any refinery in Europe.

Considering the reliability and completeness of the data sources used to establish the LCI Eurobitume estimates that there is high accuracy for the most relevant flows in the bitumen production chain: crude oil consumption, natural gas consumption, emission to air of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_X), methane (CH_4) and Non Methane Volatile Organic Compounds (NMVOC). For that reason, Eurobitume believes that this LCI is suitable for analysing environmental impact indicators such as;

- Abiotic depletion, non-renewable, fossil energy;
- Global Warming Potential;
- Ozone depletion;
- Acidification;
- Photochemical oxidation.

The LCI is less suitable for the analysis of toxicity and ecotoxicity indicators. In this update, all the characterised results for the environmental impact categories and characterisation methods in EN 15804+A1 and EN 15804+A2 are provided in Appendix 4.

6.1 Additional processing of bitumen

Bituminous binder can also be processed to adjust some properties before its use in final construction products. This includes, as example, blends of different bitumen grades at a depot, polymer modification, manufacture of bitumen emulsion, bitumen blending with additives or extenders. In this context the LCI of the new blend will be determined considering;

- Raw materials, A1, with bitumen and the present LCI can be used, the additional raw materials either polymer, additive, water, etc;
- Transport, A2, of the raw materials from the gate of the refinery to the plant or the depot where the final binder will be processed;
- Process, A3, including storage of the bitumen and other materials, the specific process if any to make the end binder;
- In this context the environmental impacts of each stage A1 to A3 should be taken into account. This includes any positive or negative (credit) impacts such as the biogenic carbon;
- The final results can be further used as inputs for raw materials in the final product.

6.2 Example of calculation

The 2020 LCI and this supplementary update can be used as input for further LCA or EPD calculations [11]. Eurobitume considers this LCI to be suitable for use to reflect bitumen production in Europe. As a reference example, the Green House Gas contribution (GHG) as reported in section 5 will be 160 kg CO_2eq per tonne of bitumen at the refinery gate not including the infrastructure.

For a typical asphalt mixture, assuming a binder content of 5%, bitumen will contribute, as a raw material (excluding secondary transportation);

- 160*5% = 8 kg CO_2eq per tonne of asphalt mixture.

6.3 Reliability of data

For certain applications, such as green public procurement, environmental data have, from time to time, been requested on a project basis. Eurobitume considers that average data for bitumen production are the most suitable for such applications for the following reasons:

- Crude oil extraction and transportation comprise the majority of the energy use. As demonstrated in section 5.2, the energy and emissions for extraction of crude oil vary significantly on a year-to-year basis. Furthermore, within a complex refinery it is unlikely that detailed information on crude origin would be available. Data are not available at the level of individual oil fields, but only on a regional basis.
- The fuel consumption of a crude oil carrier (ship) is also an important contributor to the overall environmental impact and is highly dependent on the speed of the vessel, e.g. a 10% increase in speed can lead to a 50% increase in fuel consumption. For individual cargoes it is not possible to know the actual speed of the vessel and therefore the actual fuel consumption. For this reason, average values are the only practical means for allocation of emissions associated with crude oil transport.

For the above reasons Eurobitume believes that it is not possible to obtain reliable data on either a specific crude oil cargo, or refinery basis. Therefore, it is recommended that the data provided in this report should be used as a general figure for bitumen in Europe in an environmental declaration.

6.4 Feedstock *Energy*

Bitumen is derived from crude oil, therefore it has feedstock energy. However, since it is unlikely the feedstock energy will be released, as asphalt mixtures are not used as a source of fuel, feedstock energy should be reported separately according to EN 15804, Table 4 *"Use of non-renewable primary energy resources used as raw materials"*.
Most refinery products, apart from bitumen, are combusted as fuels, or otherwise disposed of after use. However, bitumen used in asphalt mixtures, or roofing membranes has a service life that is typically measured in decades and old asphalt is widely re-used in new asphalt mixtures at the end of life, therefore the product is not consumed. This should be reflected at the end of life of the construction product when the bitumen is re-used in new asphalt. When bitumen is used in construction products it does not emit greenhouse gas and its energy content is not lost. The benefits from re-use should be highlighted in section D of an Environmental Product Declaration.

7. SUMMARY REMARKS

Considering the reliability and the completeness of data used to establish the LCI, Eurobitume estimates that there is high accuracy for the most relevant flows in the bitumen production chain: crude oil consumption, natural gas consumption, emission to air of carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_X), methane (CH_4) and non-methane volatile organic compounds (NMVOC). For that reason, this LCI is suitable for analysing environmental impact indicators such as: abiotic depletion non-renewable fossil energy, global warming potential, ozone depletion, acidification, photochemical oxidation. This LCI is not suitable for analysing toxicity and eco-toxicity indicators.

APPENDIX 1 – INFRASTRUCTURE DATA

(Update related to Appendix 1 of the 2020 LCI)

The ecoinvent database gives some information on infrastructure needed for crude oil extraction, transport and refining. Some of these values have been revised, based on the report: Life-Cycle inventories of crude oil extraction, Christoph Meili; Niels Jungbluth; Jasmin Annaheim (2018) ESU-services Ltd.

11.1.1.3. Transport infrastructure

In ecoinvent, the pipeline inventory is given for 1 m of pipeline. This inventory dataset does not take the production location into account. In the process "Transport, pipeline, onshore, petroleum {RoW}", the distance of pipeline that is used to transport one tkm of crude oil is:

$$9{,}46 \times 10^{-9} \text{ km pipeline per tkm}$$

The distance to transport the oil through pipelines is 1800 km. Then, the length of pipeline needed per kg of crude oil is:

$$9{,}46 \times 10^{-9} \times 1\,000 \times 1\,800 / 1\,000 = 1{,}70 \times 10^{-5} \text{ m pipeline per kg}$$

The same calculation must be performed for the tanker. The ecoinvent process "Transport, freight, sea, transoceanic ship {GLO}" mentions the use of a tanker, with the following figure:

$$9{,}80 \times 10^{-12} \text{ tanker per tkm}$$

The oil is transported over a distance of 7456 km.
The amount of tanker used per kg of crude oil is:

$$9{,}8 \times 10^{-11} \times 1\,000 \times 7456 / 1\,000 = 7{,}31 \times 10^{-8} \text{ tanker per kg}$$

11.1.1.4. Refinery infrastructure

In ecoinvent, the inventory of refinery is used, and the amount of refinery is based on the inventory "Pitch {Europe without Switzerland}| petroleum refinery operation | Cut-off, U".

- Amount of refinery per kg of bitumen:

$$3{,}5619 \times 10^{-11} \text{ refinery per kg}$$

APPENDIX 2 – COMPARISON FOR SHIP TRANSPORTATION WITH ECOINVENT DATA

(Update related to Appendix 2 of the 2020 LCI)

The table below summarizes the amount of fuel oil and direct emissions caused by the combustion of heavy fuel oil in the ecoinvent dataset and in the Eurobitume LCI.

		Ecoinvent v3.6 dataset	Eurobitume values
Amount of fuel oil - kg/tkm		0,0016	0,0010
Emissions index (g/kg fuel)	CO_2	3 122	2 370
	SO_2	43,4	52,8 to 2,0
	NO_X	64,9	78,5
	NMVOC	2,4	3,1
	CO	2,6	2,8
	PM	5,8	7,3

In ecoinvent, the amount of fuel consumed is based on data from 1993, whereas Eurobitume's data for fuel consumption is based on Wärtsilä Aframax data sheet and emissions profile is from Third IMO Greenhouse Gas Study 2014 and Fourth IMO Greenhouse Gas Study 2020 for SO_2 emissions. This data is more recent and more representative of type of fuel and type of ship used to transport European crude oil.

APPENDIX 3 – COMPARISON BETWEEN THE 2020 LCI AND THE 2021 UPDATE

The 2021 update involved both an activity data update and a background database update from ecoinvent 3.5 to ecoinvent 3.6. The figures below present the differences between the 2020 LCI and the 2021 update, and which differences are attributed to the activity data update compared to the differences attributed to the background database update. The figures are shown for both the main LCI and the LCIA results.

Figure 6. Differences in the LCI between the 2020 LCI and the 2021 update (on a selection of the main elementary flows)

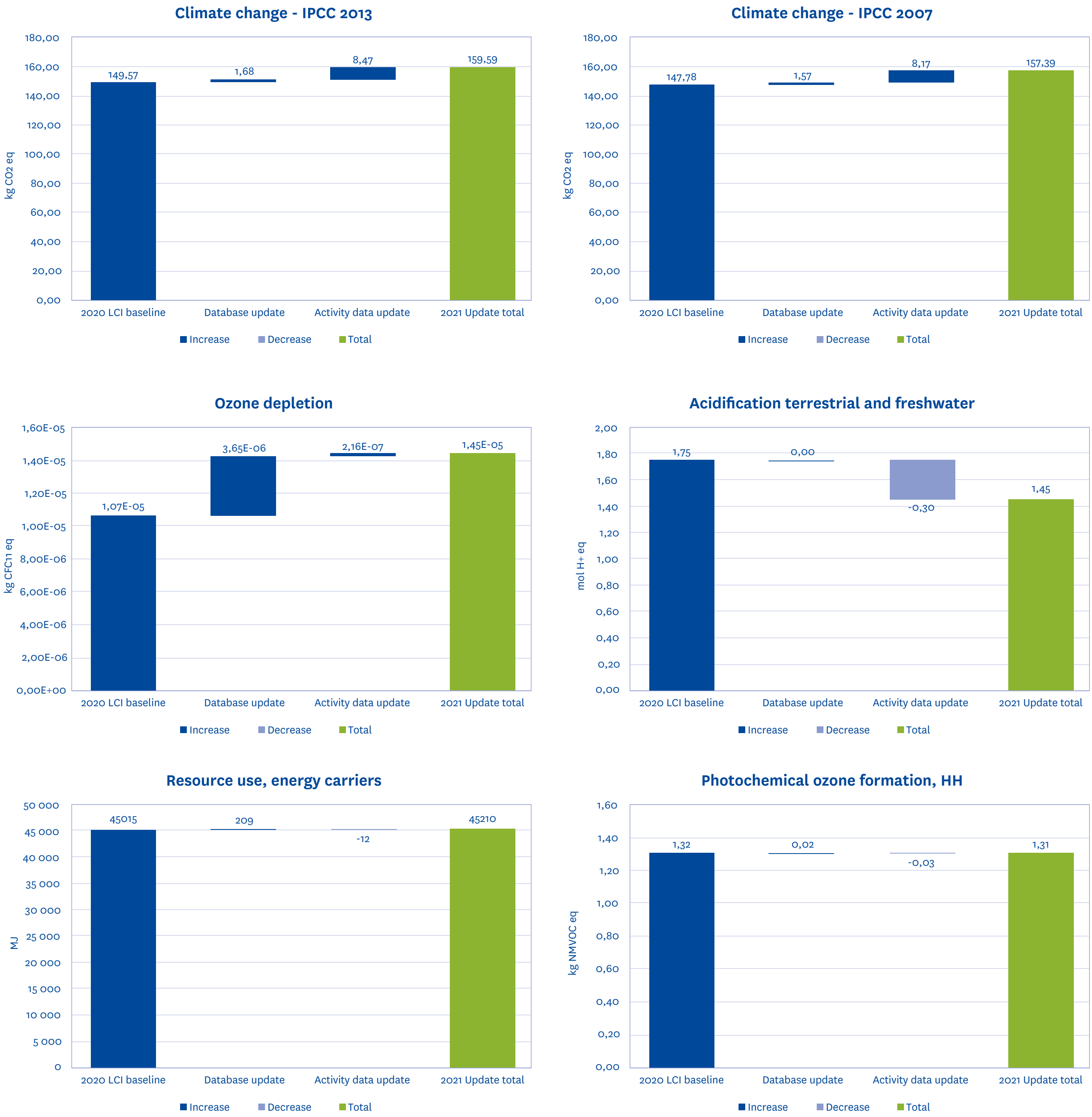

Figure 7. Differences in the LCIA results between the 2020 LCI and the 2021 update

APPENDIX 4 – LIFE-CYCLE IMPACT ASSESSMENT FOR THE EN 15804+A1 AND EN 15804+A2 INDICATORS

Below are the LCIA results for the EN 15804+A1 and EN 15804+A2.

It should be noted that a flow correction was added for the total primary use of non-renewable energy. Indeed, in characterisation methods the elementary flow of crude oil from nature is considered as an energy resource and is hence counted as non-renewable process energy.

However, in the case of bitumen, crude oil is considered a raw material for the production of bitumen. Hence the consumption of crude oil is in this case considered as non-renewable raw material energy. A lower heating value of 41,87 MJ/kg was used, which is the value used in the SimaPro characterisation method.

Table 15. Potential environmental impact for the production of 1 tonne of paving grade bitumen with the EN 15804+A1 indicators – without infrastructure

Impact category	Unit	Crude oil production	Transportation	Refining step	Storage	Total
Global warming potential	kg CO_2 eq	1,08E+02	2,11E+01	2,16E+01	6,44E+00	1,57E+02
Ozone depletion potential	kg CFC_{11} eq	2,69E-06	4,45E-06	4,44E-06	2,89E-07	1,19E-05
Acidification potential	kg SO_2 eq	6,38E-01	4,07E-01	9,49E-02	2,26E-02	1,16E+00
Eutrophication potential	kg PO_4 eq	4,65E-01	1,29E-01	8,22E-03	4,55E-03	6,07E-01
Photochemical ozone formation	kg C_2H_4 eq	2,45E-02	5,25E-03	3,56E-03	8,39E-04	3,41E-02
Abiotic depletion potential – elements	kg Sb eq	3,75E-05	5,90E-07	8,17E-07	1,41E-06	4,04E-05
Abiotic depletion potential – fossil	MJ	4,44E+04	3,44E+02	3,42E+02	2,47E+01	4,51E+04
Use of renewable primary energy excluding renewable primary energy resources used as raw material	MJ	4,50E+01	5,27E-01	2,73E-01	4,10E+00	4,99E+01
Use of renewable primary energy resources used as raw material	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Total use of renewable primary energy resources	MJ	4,50E+01	5,27E-01	2,73E-01	4,10E+00	4,99E+01
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material	MJ	1,43E+03	3,37E+02	3,34E+02	3,94E+01	2,14E+03
Use of non-renewable primary energy resources used as raw material	MJ	4,19E+04	0,00E+00	0,00E+00	0,00E+00	4,19E+04
Total use of non-renewable primary energy resources	MJ	4,33E+04	3,37E+02	3,34E+02	3,94E+01	4,40E+04
Use of secondary material	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of renewable secondary fuels	kg CFC-11 eq	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of non-renewable secondary fuels	mol H^+ eq	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Net use of freshwater	MJ	2,61E-01	5,31E-03	3,49E-01	1,98E-02	6,35E-01
Hazardous waste disposed	kg NMVOC eq	1,56E-01	1,19E-02	8,35E-03	1,65E-02	1,92E-01
Non-hazardous waste disposed	kg CO_2 eq	1,06E+00	1,82E-01	1,00E-01	2,30E-01	1,57E+00
Radioactive waste disposed	kg CO_2 eq	4,96E-01	2,49E-03	2,48E-03	2,56E-04	5,02E-01
Components for reuse	kg CFC-11 eq	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for recycling	mol H^+ eq	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for energy recovery	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy - total	kg NMVOC eq	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Table 16. Potential environmental impact for the production of 1 tonne of paving grade bitumen with the EN 15804+A1 indicators – with infrastructure

Impact category	Unit	Crude oil production	Transportation	Refining step	Storage	Total
Global warming potential	kg CO_2 eq	1,51E+02	3,36E+01	2,25E+01	6,48E+00	2,13E+02
Ozone depletion potential	kg CFC_{11} eq	0,00E+00	5,29E-06	4,50E-06	2,93E-07	1,01E-05
Acidification potential	kg SO_2 eq	8,93E-01	4,65E-01	1,01E-01	2,29E-02	1,48E+00
Eutrophication potential	kg PO_4 eq	5,57E-01	1,56E-01	1,08E-02	4,66E-03	7,28E-01
Photochemical ozone formation	kg C_2H_4 eq	4,04E-02	8,68E-03	3,99E-03	8,56E-04	5,39E-02
Abiotic depletion potential – elements	kg Sb eq	8,89E-04	9,98E-05	2,10E-04	3,82E-06	1,20E-03
Abiotic depletion potential – fossil	MJ	4,49E+04	4,83E+02	3,52E+02	2,52E+01	4,58E+04
Use of renewable primary energy excluding renewable primary energy resources used as raw material	MJ	6,56E+01	1,70E+01	1,29E+00	4,17E+00	8,80E+01
Use of renewable primary energy resources used as raw material	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Total use of renewable primary energy resources	MJ	6,56E+01	1,70E+01	1,29E+00	4,17E+00	8,80E+01
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material	MJ	2,05E+03	5,49E+02	3,48E+02	4,00E+01	2,99E+03
Use of non-renewable primary energy resources used as raw material	MJ	4,19E+04	0,00E+00	0,00E+00	0,00E+00	4,19E+04
Total use of non-renewable primary energy resources	MJ	4,39E+04	5,49E+02	3,48E+02	4,00E+01	4,49E+04
Use of secondary material	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of renewable secondary fuels	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of non-renewable secondary fuels	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Net use of freshwater	m^3	6,54E-01	1,18E-01	3,56E-01	2,02E-02	1,15E+00
Hazardous waste disposed	kg	5,45E+00	9,37E-01	1,33E-01	2,14E-02	6,54E+00
Non-hazardous waste disposed	kg	2,05E+01	8,08E+00	9,09E-01	2,97E-01	2,98E+01
Radioactive waste disposed	kg	4,99E-01	3,14E-03	2,52E-03	2,58E-04	5,05E-01
Components for reuse	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for recycling	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for energy recovery	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy - total	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Table 17. Potential environmental impact for the production of 1 tonne of paving grade bitumen with the EN 15804+A2 indicators – without infrastructure

Impact category	Unit	Crude oil production	Transportation	Refining step	Storage	Total
Global warming potential - Total	kg CO_2 eq	1,13E+02	2,13E+01	2,18E+01	6,51E+00	1,63E+02
Global warming potential - Fossil	kg CO_2 eq	1,13E+02	2,13E+01	2,18E+01	6,46E+00	1,62E+02
Global warming potential - Biogenic	kg CO_2 eq	2,91E-01	1,58E-02	7,85E-03	4,02E-02	3,55E-01
Global warming potential - LULUC	kg CO_2 eq	1,55E-02	2,14E-04	7,13E-05	2,65E-03	1,85E-02
Ozone layer depletion potential	kg CFC_{11} eq	2,93E-06	5,63E-06	5,62E-06	3,04E-07	1,45E-05
Acidification potential	mol H+ eq	7,48E-01	5,67E-01	1,09E-01	2,62E-02	1,45E+00
Eutrophication potential - freshwater	kg P eq	4,04E-03	1,50E-04	4,03E-04	1,11E-03	5,71E-03
Eutrophication potential - marine	kg N eq	1,04E-01	2,35E-01	1,34E-02	3,05E-03	3,56E-01
Eutrophication potential - terrestrial	mol N eq	1,13E+00	2,63E+00	1,21E-01	3,17E-02	3,91E+00
Photochemical ozone formation	kg NMVOC eq	6,08E-01	6,44E-01	4,39E-02	9,36E-03	1,31E+00
Abiotic resource depletion - minerals	kg Sb eq	3,74E-05	5,88E-07	8,16E-07	1,39E-06	4,02E-05
Abiotic resource depletion - fossil fuel	MJ	4,45E+04	3,45E+02	3,42E+02	3,52E+01	4,52E+04
Water need	m³	2,96E+00	-1,25E-01	1,45E+01	2,30E-01	1,75E+01
Particulate matter emissions	disease inc.	1,09E-06	4,36E-07	1,30E-06	3,25E-07	3,16E-06
Ionising radiation, human health	kBq U-235 eq	3,03E+02	1,55E+00	1,51E+00	6,61E-01	3,07E+02
Ecotoxicity, freshwater	CTUe	2,31E+03	1,13E+02	1,40E+02	1,21E+01	2,57E+03
Human health toxicity, cancer	CTUh	5,13E-09	5,47E-09	1,86E-09	4,75E-10	1,29E-08
Human health toxicity, non-cancer	CTUh	2,65E-07	1,20E-07	1,15E-07	3,13E-08	5,31E-07
Soil Quality Potential Index	Pt	1,55E+01	1,03E+00	6,13E-01	4,52E+00	2,17E+01
Use of renewable primary energy excluding renewable primary energy resources used as raw material	MJ	4,50E+01	5,27E-01	2,73E-01	4,10E+00	4,99E+01
Use of renewable primary energy resources used as raw material	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Total use of renewable primary energy resources	MJ	4,50E+01	5,27E-01	2,73E-01	4,10E+00	4,99E+01
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material	MJ	1,43E+03	3,37E+02	3,34E+02	3,94E+01	2,14E+03
Use of non-renewable primary energy resources used as raw material	MJ	4,19E+04	0,00E+00	0,00E+00	0,00E+00	4,19E+04
Total use of non-renewable primary energy resources	MJ	4,33E+04	3,37E+02	3,34E+02	3,94E+01	4,40E+04
Use of secondary material	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of renewable secondary fuels	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of non-renewable secondary fuels	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Net use of freshwater	m³	2,61E-01	5,31E-03	3,49E-01	1,98E-02	6,35E-01
Hazardous waste disposed	kg	1,56E-01	1,19E-02	8,35E-03	1,65E-02	1,92E-01
Non-hazardous waste disposed	kg	1,06E+00	1,82E-01	1,00E-01	2,30E-01	1,57E+00
Radioactive waste disposed	kg	4,96E-01	2,49E-03	2,48E-03	2,56E-04	5,02E-01
Components for reuse	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for recycling	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for energy recovery	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy - total	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

Table 18. Potential environmental impact for the production of 1 tonne of paving grade bitumen with the EN 15804+A2 indicators – with infrastructure

Impact category	Unit	Crude oil production	Transportation	Refining step	Storage	Total
Global warming potential - Total	kg CO_2 eq	1,58E+02	3,43E+01	2,27E+01	6,55E+00	2,21E+02
Global warming potential - Fossil	kg CO_2 eq	1,57E+02	3,42E+01	2,27E+01	6,51E+00	2,21E+02
Global warming potential - Biogenic	kg CO_2 eq	3,24E-01	8,35E-02	9,18E-03	3,80E-02	4,55E-01
Global warming potential - LULUC	kg CO_2 eq	5,86E-02	2,75E-02	1,08E-03	2,73E-03	9,00E-02
Ozone layer depletion potential	kg CFC_{11} eq	8,43E-06	6,48E-06	5,69E-06	3,08E-07	2,09E-05
Acidification potential	mol H+ eq	1,09E+00	6,38E-01	1,16E-01	2,66E-02	1,87E+00
Eutrophication potential - freshwater	kg P eq	1,67E-02	6,57E-03	1,04E-03	1,14E-03	2,55E-02
Eutrophication potential - marine	kg N eq	2,23E-01	2,53E-01	1,48E-02	3,13E-03	4,94E-01
Eutrophication potential - terrestrial	mol N eq	2,42E+00	2,81E+00	1,36E-01	3,27E-02	5,40E+00
Photochemical ozone formation	kg NMVOC eq	1,02E+00	7,00E-01	4,92E-02	9,65E-03	1,78E+00
Abiotic resource depletion - minerals	kg Sb eq	8,88E-04	9,98E-05	2,10E-04	3,79E-06	1,20E-03
Abiotic resource depletion - fossil fuel	MJ	4,50E+04	5,12E+02	3,53E+02	3,57E+01	4,59E+04
Water need	m³	1,73E+01	2,86E+00	1,47E+01	2,42E-01	3,51E+01
Particulate matter emissions	disease inc.	4,22E-06	1,33E-06	1,37E-06	3,28E-07	7,25E-06
Ionising radiation, human health	kBq U-235 eq	3,06E+02	3,38E+00	1,60E+00	6,64E-01	3,12E+02
Ecotoxicity, freshwater	CTUe	1,31E+04	4,40E+02	2,40E+02	1,88E+01	1,38E+04
Human health toxicity, cancer	CTUh	1,11E-07	2,63E-08	5,16E-09	6,07E-10	1,43E-07
Human health toxicity, non-cancer	CTUh	1,61E-06	3,83E-07	1,62E-07	3,35E-08	2,19E-06
Soil Quality Potential Index	Pt	7,06E+03	9,48E+01	8,20E+01	6,71E+00	7,24E+03
Use of renewable primary energy excluding renewable primary energy resources used as raw material	MJ	6,56E+01	1,70E+01	1,29E+00	4,17E+00	8,80E+01
Use of renewable primary energy resources used as raw material	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Total use of of renewable primary energy resources	MJ	6,56E+01	1,70E+01	1,29E+00	4,17E+00	8,80E+01
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw material	MJ	2,05E+03	5,49E+02	3,48E+02	4,00E+01	2,99E+03
Use of non-renewable primary energy resources used as raw material	MJ	4,19E+04	0,00E+00	0,00E+00	0,00E+00	4,19E+04
Total use of of non-renewable primary energy resources	MJ	4,39E+04	5,49E+02	3,48E+02	4,00E+01	4,49E+04
Use of secondary material	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of renewable secondary fuels	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Use of non-renewable secondary fuels	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Net use of freshwater	m³	6,54E-01	1,18E-01	3,56E-01	2,02E-02	1,15E+00
Hazardous waste disposed	kg	5,45E+00	9,37E-01	1,33E-01	2,14E-02	6,54E+00
Non-hazardous waste disposed	kg	2,05E+01	8,08E+00	9,09E-01	2,97E-01	2,98E+01
Radioactive waste disposed	kg	4,99E-01	3,14E-03	2,52E-03	2,58E-04	5,05E-01
Components for reuse	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for recycling	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Materials for energy recovery	kg	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Exported energy - total	MJ	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00

REFERENCES

1 EN 15804:2012+A2:2019+AC:2021 - Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products

2 IOGP reports: Environmental performance indicators; International Association of Oil & Gas Producers https://www.iogp.org/bookstore/product/environmental-performance-indicators-2019-data/

3 BP Statistical Review of World Energy 2017

4 https://ec.europe.eu/energy/en/data-analysis/eu-crude-oil-imports

5 Life-cycle inventories of crude oil extraction, Christoph Meili; Niels Jungbluth; Jasmin Annaheim (2018) ESU-services Ltd.

6 Efficient Aframax Design Providing Solutions for Emissions Legislation (SO_x and NO_x), https://www.wartsila.com

7 https://www.searates.com

8 Sulphur dioxide emissions from oil refineries in Europe (2015), Concawe report 5/18

9 Fourth IMO Greenhouse Gas Study 2020; Published in 2021 by the International Maritime Organization

10 Emission factors for CH_4, NO_x, particulates and black carbon for domestic shipping in Norway, revision 1; Nielsen J, Stenersen D, Norwegian Marine [3] Technology Technology Research Institute (Marintek), Report MT22 A10—199, 2010.

11 Guidance for preparing Product Category Rules (PCR) and Environmental Product declarations (EPD) for asphalt mixtures, EAPA 2017, https://eapa.org/wp-content/uploads/2018/07/GCA-17-N215-EAPA-Guidance.pdf

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