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Annex A: Development of the petroleum refining under the EU ETS

Annex to the final report of project no.
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by:

Bettina Schäppi, Sophie Kaufmann, Alexandra Mäder, Jürg Füssler
INFRAS, Zurich

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Final report

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Overview and country level analysis from 2005 - 2017

by

Bettina Schächli, Sophie Kaufmann, Alexandra Mäder, Jürg
Füssler
INFRAS, Zurich

On behalf of the German Environment Agency

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Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
buergerservice@uba.de
Internet: www.umweltbundesamt.de

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INFRAS
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Switzerland

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Alexandra Zirkel, Claudia Gibis, Annett Hohlfeld

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Abstract: Drivers of GHG emissions from petroleum refining between 2005 and 2017

The present report summarizes the main trends and drivers of the petroleum refining industry covered by the European Emission Trading System (EU ETS 1) in the time period 2005-2017 in the EU28 and provides a compilation of key figures on the petroleum refining industry for selected countries. The report focuses on the countries with the highest contribution to total emissions within the refining industry of the EU28 (i.e. Germany, Italy, France, Spain, Netherlands and Poland). It shows the evolution of GHG emissions and the refinery throughput over time and the change in emission and energy intensity as well as shares of different energy carriers in the energy use of the petroleum refining plants. Besides the characteristics of the petroleum refining process, the report provides an overview of the evolution of the final demand of oil and petroleum products and an overview of the largest production facilities per country.

External factors such as the demand for oil and petroleum products from the industry, the transport and the buildings sector seem to be the main driver of emissions from the refining industry in the time period 2005-2017. In most countries, the evolution of emissions follows the trend in the demand for oil and petroleum products, which shows a decreasing trend in most countries. Except for Poland, emissions of the refining industry show a decreasing trend, whereas the refinery throughput increases in the same time period (2005-2017). One reason for the observed decrease in emissions is the substitution of natural gas for liquid fuels in the refining process. In some countries, there has also been a conversion of conventional refineries into biorefineries (e.g. France and Italy).

Kurzbeschreibung: Treiber der Entwicklung der Treibhausgasemissionen der Erdölraffinerien

Der vorliegende Bericht fasst die wichtigsten Trends und Einflussfaktoren der Treibhausgasemissionen des in den europäischen Emissionshandel (EU-ETS 1) einbezogenen Erdölraffinerie-sektors im Zeitraum 2005-2017 in der EU28 zusammen und zeigt die wichtigsten Kennzahlen der Emissionsentwicklung für ausgewählte Länder. Der Bericht fokussiert auf die Länder mit dem höchsten Anteil an den Gesamtemissionen aus dem Raffinerie-sektors der EU28 (d.h. Deutschland, Italien, Frankreich, Spanien, Niederlanden und Polen). Der Bericht zeigt die zeitliche Entwicklung der Treibhausgasemissionen und dem Durchsatz der Raffinerien sowie die Veränderung der Emissions- und Energieintensität und die Anteile der verschiedenen Energieträger am Brennstoffmix, der in den Erdölraffinerien eingesetzt wird. Neben den Kennzahlen der Erdölraffinerien gibt der Bericht auch einen Überblick über die Entwicklung der Nachfrage nach Erdölprodukten über die größten Produktionsanlagen pro Land.

Externe Faktoren wie die Nachfrage nach Erdöl und Erdölzerzeugnissen in der Industrie, im Verkehr und im Gebäudesektor scheinen im Zeitraum 2005-2017 die Hauptursache für die Emissionen der Raffinerieindustrie zu sein. In den meisten Ländern folgt die Entwicklung der Emissionen dem Trend der Nachfrage nach Erdölprodukten, welche seit 2005 in den meisten Ländern deutlich abgenommen hat. Zudem ist eine Substitution von fossilen Kraftstoffen durch Biodiesel und Bioethanol zu beobachten. Mit Ausnahme von Polen zeigen die Emissionen der Raffinerieindustrie einen rückläufigen Trend, wohingegen der Raffineriedurchsatz gleichzeitig angestiegen ist (2005-2017). Ein Grund für die beobachtete Abnahme der Emissionen ist die Substitution von flüssigen Brennstoffen durch Erdgas im Brennstoffmix der Raffinerien. In einigen Länder erfolgte zudem eine Umwandlung von konventionellen Raffinerien in Bioraffinerien (z.B. Frankreich und Italien).

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List of abbreviations

AR	Atmospheric Residue
CO₂	Carbon dioxide
CO₂eq	Carbon dioxide equivalent
CCS	Carbon capture and storage
CIS	Commonwealth of Independent States
EU	European Union
EU ETS	European Emission trading system
EUA	European Emission Allowances
EUTL	EU Transaction Log
GHG	Greenhouse gas
GJ	gigajoule
GUS	Gemeinschaft unabhängiger Staaten
kt	kilotonne
LPG	Liquid Petroleum Gas
Mt	Megatonne
NCI	Nelson complexity index
PJ	petajoule
t	tonne
THG	Treibhausgas

Summary

General remark: In some countries (e.g. Germany), facilities that generate electricity for refineries were assigned to the activity “combustion installations” before 2013, whereas since 2013, they are assigned to activity 21 (“refining of mineral oil”). Emissions have therefore been at a higher level since 2013 than before and the data from 2013 on is not directly comparable with the time period 2005 until 2012. This different attribution of emissions to industry activities in EU ETS may also be one possible reason for differences between the national emission intensity values.

This report summarises the main trends and drivers of the refinery sector's greenhouse gas emissions in the EU28 from 2005 to 2017, analyses the countries with the highest contribution of total EU28 emissions and presents the key figures of the selected countries' emission trends in the form of fact sheets. This report aims to describe the main developments in the sector in the period from 2005 to 2017, i.e. before the end of the Third EU ETS¹ trading period in 2020.

- ▶ With the exception of Poland, greenhouse gas (GHG) emissions from petroleum refining decreased in all countries studied between 2013 and 2017. With 11.7 % France shows the highest reduction in total GHG emissions from the refining industry since 2013.
- ▶ Refinery throughput (see definitions in section 2.2.1) increased at the same time, with the highest increase observed in Spain (+9.5%).
- ▶ This leads to a decrease in emission intensity between 2013 and 2017. The highest decrease was observed for France (-13.5%) and the lowest decrease was observed for Poland (-5.2%).
- ▶ In contrast to the increased refinery throughput between 2013 and 2017, the refinery capacity (see definitions in section 2.2.1) decreased in most of the countries analysed. Therefore, in this time period, capacity utilization (see definitions in section 2.2.1) increased, except for the Netherlands.
- ▶ The main driver of the observed evolution of GHG emissions from the refining industry between 2005 and 2017 is the declining **demand for petroleum products**, such as gasoline as well as light and heavy fuel oil. Apart from Poland, all investigated countries show a declining trend in the demand of oil and petroleum products since 2005. There is however a slight increase since 2014 of the consumption of oil productions (+4%).
- ▶ The shift in demand for certain products is of importance for the emissions: The share of gas oil and diesel oil increased while the share of motor gasoline and fuel oil decreased between 2013 and 2019. In addition, in the transport sector there is some substitution of fossil fuels by biofuels. These changes could explain the decreasing GHG emissions of the refinery sector between 2013 and 2017 while consumption increased.
- ▶ As most of the crude oil is imported from countries that do not show large differences in terms of the atmospheric residue (i.e. Africa, EU, CIS), the influence of the atmospheric

¹ Whenever the term EU ETS is used, it refers to the EU ETS 1 covering operators of large energy installations and energy-intensive industrial plants as well as aircraft and ship operators.

residue on GHG emissions from the refining sector is of minor importance in the countries considered in the present report.

- ▶ The petroleum refining industry in different countries shows different levels of success to reduce GHG emission intensity of the refining process by means of substituting liquid fuels by natural gas and by converting existing petroleum refining plants to biorefineries.
 - In most countries a decreasing trend is observed for liquid fuels used in the petroleum refining process and an increase in natural gas, except for Poland, where the share of liquid fuels is again increasing since 2013.
 - A few petroleum refineries in Italy and in France were converted to biorefineries. In Italy, there are currently two biorefineries in operation, one in Venice and another one in Gela, Sicily. In France, the petroleum refining plant “Raffinerie de Provence” in La Mède owned by TOTAL Raffinage France was converted into a biorefinery in 2015 and went into operation in 2019. It produces both biodiesel and bio-jet fuel for the aviation industry and processes vegetable oils as well as animal fats, cooking oil etc.
 - The capacity weighted average Nelson index (see definition in section 2.4.3) does not seem to have a strong impact on the GHG emissions of the refining industry at the national level. Possible correlations should be further investigated at the plant level.

Table 1: Selected Member States: Key figures of the petroleum refining industry in 2017

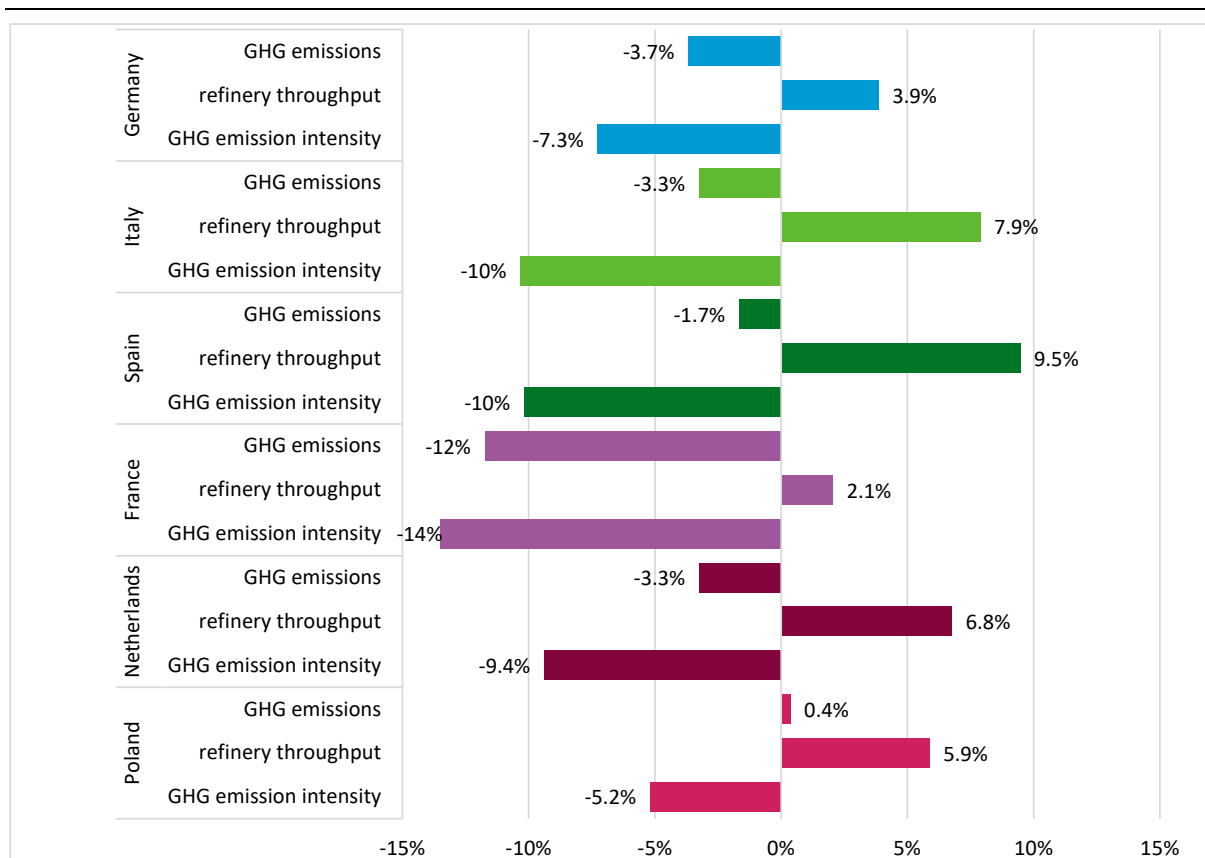
Petroleum industry characteristics	Unit	Germany	Italy	Spain	France	Netherlands	Poland	Source
GHG emissions	Mt CO ₂ eq	24	18	14	10	10	4	EUTL 2020
Total refinery throughput	Mt	104	76	67	60	60	27	UN 2020
GHG emission intensity	t CO ₂ eq / t throughput	0.23	0.24	0.21	0.17	0.17	0.15	EUTL 2020, UN 2020
Energy consumption	PJ	288	162	202	110	83	46	Eurostat 2022a
Energy intensity	GJ/t crude oil	2.8	2.1	3.0	1.8	1.4	1.7	Eurostat 2022a, UN 2020
Nelson index (capacity-weighted average)	-	8.14	9.25	9.61	6.7	7.7	9.75	abarrelfu II (2020)

Petroleum industry characteristics	Unit	Germany	Italy	Spain	France	Netherlands	Poland	Source
Trends in refinery capacity (2013-2017)	%	-7%	-10%	11%	-7%	11%	0%	UN 2020

Key figures of the petroleum refining industry in 2017 in the analysed countries.

Sources: see last column

Figure 1: Selected Member States: Change in key figures of the petroleum refining industry between 2013 and 2017



Change in key figures of the petroleum refining industry between 2013 and 2017 in the analysed countries.

Source: EUTL 2020, UN 2020, Eurostat 2022a

As mentioned above the present report aims to describe the main developments in the sector before the end of the 3rd EU ETS trading period and provides a basis for further research on the impact of the EU ETS on GHG emissions especially after the year 2017.

In the years 2019 to 2021 the pandemic-related adjustment of production in refineries in 2020 and 2021 also had an impact on the emissions trend in the industry. However, Refinery emissions increased moderately after 2021 due to increased demand for fuels as the travel industry recovered from the removal of restrictions and also the economic recovery following the COVID-19 pandemic.

Unlike other sectors of the EU ETS, emissions and production didn't decrease during the first years of the Russian war of aggression in Ukraine. In 2022, emissions of the refinery sector were again close to the level of 2019. This development is not addressed in this

report. Similarly, the changes in the macroeconomic framework as well as developments on the energy markets since then and the potential impact of the 'Fit for 55' framework agreed for 2023 cannot be taken into account. Furthermore, allowance prices have risen substantially since 2018 and continued to do so also after 2019 (see e.g. DEHSt 2024 for a graphical illustration of the observed price developments).

Zusammenfassung

Allgemeine Anmerkung: In einigen Ländern (z.B. Deutschland) wurden Anlagen, die Strom für Raffinerien erzeugen, vor 2013 dem Sektor "Feuerungsanlagen" zugeordnet. Seit 2013 werden sie dem Sektor 21 ("Raffination von Mineralöl") zugeordnet. Die Emissionen liegen daher seit 2013 auf einem höheren Niveau und die Daten ab 2013 sind nicht direkt mit dem Zeitraum 2005 bis 2012 vergleichbar. Diese unterschiedliche Zuordnung der Emissionen zu den Sektoren des EU-ETS könnte auch ein möglicher Grund sein für die beobachteten Unterschiede in den nationalen Emissionsintensitäten.

Dieser Bericht fasst die wichtigsten Trends und Einflussfaktoren der Treibhausgasemissionen der Raffinerien in der EU28 von 2005 bis 2017 zusammen, analysiert die Länder mit dem höchsten Anteil an den Gesamtemissionen der und stellt die wichtigsten Zahlen zu den Emissionstrends der ausgewählten Länder in Form von Faktenblättern vor. Ziel dieses Berichts ist es, die wichtigsten Entwicklungen des Sektors im Zeitraum von 2005 bis 2017 zu beschreiben, d. h. vor dem Ende der dritten Handelsperiode des EU-ETS² im Jahr 2020.

- ▶ Mit Ausnahme von Polen sind die Treibhausgas (THG)-Emissionen der Erdölraffinerien zwischen 2013 und 2017 in allen untersuchten Ländern zurückgegangen. Der Rückgang der Treibhausgasemissionen aus dem Raffineriesektor war mit 11,7 % seit 2013 in Frankreich am größten.
- ▶ Gleichzeitig stieg der Raffineriedurchsatz (siehe Definition in Kap. 2.2.1), wobei der höchste Anstieg in Spanien zu verzeichnen war (+9,5%).
- ▶ Dies führt zu einem Rückgang der Emissionsintensität zwischen 2013 und 2017. Der stärkste Rückgang wurde für Frankreich (-13,5 %) und der geringste für Polen (-5,2 %) beobachtet.
- ▶ Im Gegensatz zum Anstieg des Raffineriedurchsatzes ist die Raffineriekapazität (siehe Definition in Kap. 2.2.1) zwischen 2013 und 2017 in den meisten der untersuchten Länder zurückgegangen. Daher ist in diesem Zeitraum die Kapazitätsauslastung (siehe Definition in Kap. 2.2.1) in den meisten Ländern angestiegen, mit Ausnahme der Niederlande.
- ▶ Hauptgrund für die beobachtete Entwicklung der THG-Emissionen der Raffinerien zwischen 2005 und 2017 ist die rückläufige **Nachfrage nach Erdölerzeugnissen**, wie beispielsweise Benzin sowie leichtes und schweres Heizöl. Mit Ausnahme von Polen weisen alle untersuchten Länder seit 2005 einen rückläufigen Trend bei der Nachfrage nach Erdöl und Erdölerzeugnissen auf, wobei jedoch seit 2014 ein leichter Anstieg des Verbrauchs von Erdölprodukten zu verzeichnen ist (+4 %).
- ▶ Die Verschiebung der Nachfrage nach bestimmten Produkten ist für die Emissionen von Bedeutung: Der Anteil von leichtem Heizöl und Diesel ist gestiegen, während der Anteil von Benzin und schwerem Heizöl zwischen 2013 und 2019 gesunken ist. Außerdem ist im Verkehrssektor eine Substitution fossiler Kraftstoffe durch Biokraftstoffe zu verzeichnen. Diese Veränderungen könnten die sinkenden THG-Emissionen des Raffineriesektors zwischen 2013 und 2017 bei gleichzeitigem Anstieg des Verbrauchs erklären.

² Wenn der Begriff EU-ETS verwendet wird, bezieht er sich auf das EU-ETS 1, das die Betreiber von großen Energieanlagen und energieintensiven Industrieanlagen sowie die Betreiber von Flugzeugen und Schiffen umfasst.

- ▶ Da der größte Teil des Rohöls aus Ländern importiert wird, die keine großen Unterschiede hinsichtlich der atmosphärischen Rückstände aufweisen (d. h. Afrika, EU, GUS), ist der Einfluss der atmosphärischen Rückstände auf die THG-Emissionen des Raffinerie-sektors in den im vorliegenden Bericht betrachteten Ländern von geringer Bedeutung.
- ▶ Die Erdölraffinerien konnten die Treibhausgasemissionen des Raffinerieprozesses durch die Substitution flüssiger Brennstoffe durch Erdgas und durch die Umstellung bestehender Erdölraffinerien auf Bioraffinerien reduzieren.
 - In den meisten Ländern ist ein rückläufiger Trend bei flüssigen Brennstoffen, die bei der Erdölraffination verwendet werden, und ein Anstieg bei Erdgas zu beobachten, mit Ausnahme von Polen, wo der Einsatz flüssiger Brennstoffe seit 2013 wieder zunimmt.
 - Einige Erdölraffinerien in Italien und Frankreich wurden auf Bioraffinerien umgestellt. In Italien sind derzeit zwei Bioraffinerien in Betrieb, eine in Venedig und eine weitere in Gela, Sizilien. In Frankreich wurde die Erdölraffinerie "Raffinerie de Provence" in La Mède, die sich im Besitz von TOTAL Raffinage France befindet, im Jahr 2015 in eine Bioraffinerie umgewandelt und ging 2019 in Betrieb. Sie produziert sowohl Biodiesel als auch Biojet-Kraftstoff für die Luftfahrtindustrie und verarbeitet Pflanzenöle sowie tierische Fette, Speiseöl usw.
 - Der kapazitätsgewichtete durchschnittliche Nelson-Index (siehe Definition in Kap. 2.4.3) scheint keinen starken Einfluss auf die Treibhausgasemissionen der Raffinerieindustrie auf nationaler Ebene zu haben. Mögliche Korrelationen sollten auf der Ebene der Anlagen weiter untersucht werden.

Table 2: Ausgewählte Mitgliedsstaaten: Kennzahlen der erdölverarbeitenden Industrie 2017

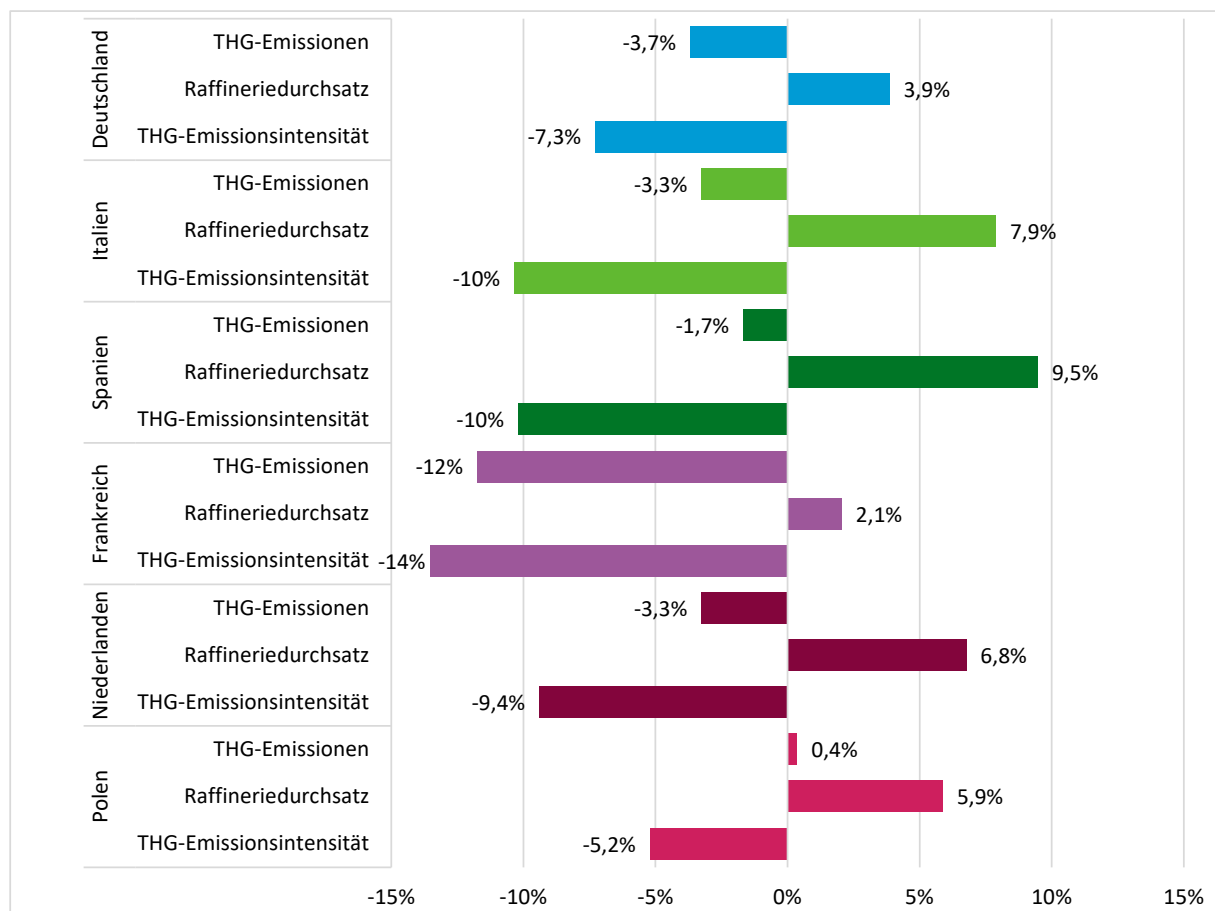
Kennzahlen Erdölraffinerien	Einheit	Deutschland	Italien	Spanien	Frankreich	Niederlande	Polen	Quelle
THG-Emissionen	Mt CO ₂ eq	24	18	14	10	10	4	EUTL 2020
Raffineriedurchsatz	Mt	104	76	67	60	60	27	UN 2020
THG-Emissionsintensität	t CO ₂ eq / t Durchsatz	0,23	0,24	0,21	0,17	0,17	0,15	EUTL 2020, UN 2020
Energieverbrauch	PJ	288	162	202	110	83	46	Eurostat 2022a

Kennzahlen Erdölraffinerien	Einheit	Deutschland	Italien	Spanien	Frankreich	Niederlande	Polen	Quelle
Energieintensität	GJ/t Rohöl	2,8	2,1	3,0	1,8	1,4	1,7	Eurostat 2022a, UN 2020
Nelson Index (kapazitäts gewichteter Durchschnitt)	-	8,14	9,25	9,61	6,7	7,7	9,75	abarrefu II (2020)
Trend in der Raffineriekapazität (2013-2017)	%	-7%	-10%	11%	-7%	11%	0%	UN 2020

Kennzahlen der Erdölraffinerien in den untersuchten Ländern im Jahr 2017.

Quelle: Siehe letzte Spalte

Figure 2: Ausgewählte Mitgliedstaaten: Veränderung der Kennzahlen der Erdölraffinerie zwischen 2013 und 2017



Veränderung der Kennzahlen der Erdölraffinerien zwischen 2013 und 2017 in den untersuchten Ländern.

Quelle: EUTL 2020, UN 2020, Eurostat 2022a

1 Introduction

The petroleum refining industry is one of the most important sources of greenhouse gas (GHG) emissions in the industrial sector since the refining process is highly energy intensive. To be in line with the Paris Agreement, GHG emissions from petroleum refining industry need to be reduced substantially. Greenhouse gas emissions from the petroleum refining industry result from the combustion of fossil fuels that produces thermal energy required for the refining process. Emissions related to the transportation of products and crude oil as well as electricity consumption are not covered by the EU emissions trading system (EU ETS³) and are therefore not accounted for in the present report.

The EU ETS is a key policy instrument for reducing greenhouse gas (GHG) emissions from energy intensive industrial sectors in Europe. Its impact on emissions of the industrial sector during the time period considered here (2005 up to 2017) is very likely to be low, however, due to very low EUA-prices before 2017. A deeper understanding of the development of the petroleum refining industry and the drivers of emissions development in the past is necessary in order to assess the potential impact of the EU ETS in the future, i.e. when the price of emission allowances is substantially higher.

The present report summarizes the main trends and drivers of the petroleum refining industry in the EU28⁴ (e.g. GHG emissions, amount of refinery throughput, emission intensities as well as the demand of oil and petroleum products) in the period from 2005 to 2017, i.e. before the end of the third ETS trading period in 2020 and provides a data base for further research on the drivers of GHG emissions development from the petroleum refining industry and on the possible impact of the EU ETS in the future.

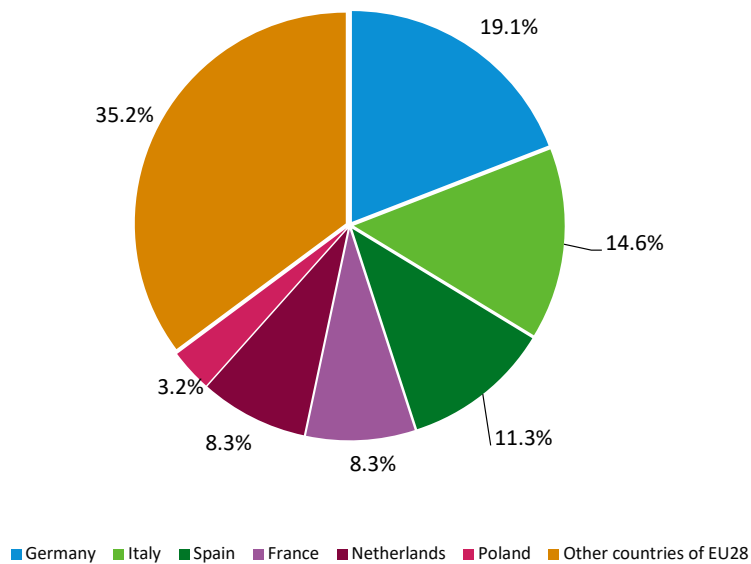
To this end, we identified countries that play an important role in the petroleum refining industry of the EU28, due to their contribution to the GHG emissions from the refining industry. For those countries, the evolution of emissions at the facility level was compiled. The selection is based on the country's contribution to total GHG emissions of the petroleum refining industry, data availability and quality, a broad representation of technologies as well as trends in GHG emissions and GHG emission intensity.

The screening finally led to the selection of the following countries: Germany, Italy, Spain, France, the Netherlands and Poland. Figure 3 shows the share of these countries' GHG emissions from the petroleum refining industry in total EU28 petroleum refining industry emissions in 2017. The countries account for 65 % of GHG emissions from the petroleum refining industry in the EU28 in 2017.

³ Whenever the term EU ETS is used, it refers to the EU ETS 1 covering operators of large energy installations and energy-intensive industrial plants as well as aircraft and ship operators.

⁴ During the reference period investigated in this report (2013-2017), UK was still part of the EU28. UK is therefore included in the present report and data is provided for EU28. The UK has left the EU and the EU ETS and runs its own ETS since the beginning of 2021.

Figure 3: Share of selected countries in total EU28 GHG emissions from the petroleum refining industry in 2017



Share in total GHG emissions in Mt CO₂eq from the petroleum refining industry of selected countries and the other countries of the EU28.

Source: EUTL 2020

In the present report we capture the full time period between 2005, the start year of EU ETS, and 2017, which corresponds to the latest available data basis at the time the report was prepared. Where available, more recent data is used (e.g. emission data, EUTL 2020).

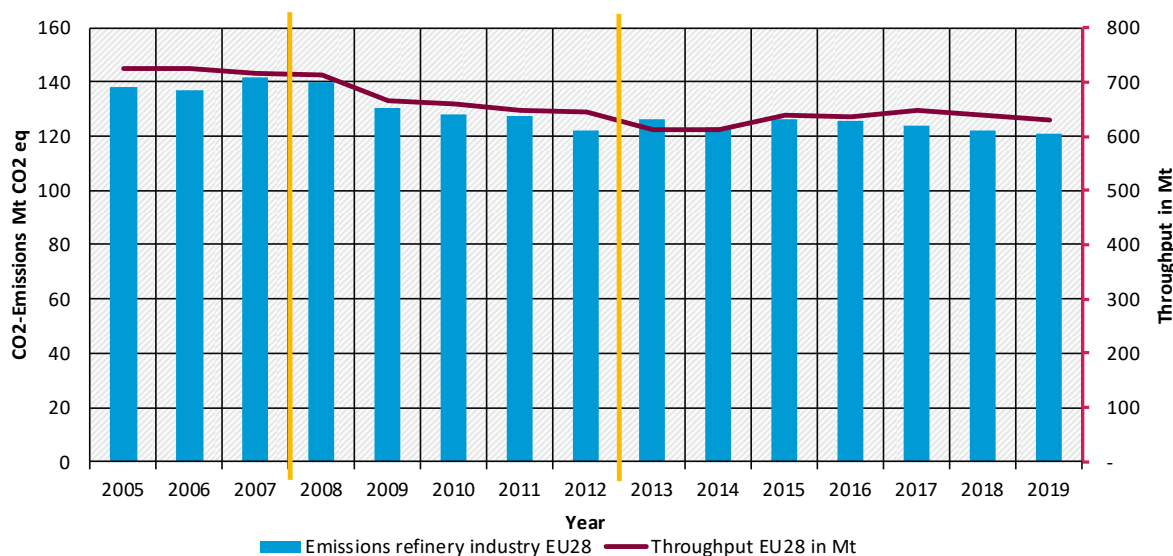
2 Overview of the refining industry in the EU ETS

2.1 Emissions of the petroleum refining industry

The following figure shows the emissions from the petroleum refining industry reporting under the EU emissions trading system. Emissions from the petroleum refining industry account for around 5 to 7.5 % of the total EU ETS emissions from stationary installations.

- ▶ Between 2013 and 2019 emissions decreased by roughly 4 % from 126 million tonnes to 121 million tonnes. Since 2005 the GHG emissions decreased even more strongly by 12 %.
- ▶ The development of the throughput (see definitions in section 2.2.1) increased by about 6 % between 2013 (612 million tonnes) and 2017 (648 million tonnes) and shows an overall declining trend from 2005 (725 million tonnes) to 2017 (-11 %).

Figure 4: Emissions from the petroleum refining industry and refinery throughput



Evolution of total GHG emissions from the refining industry and the throughput between 2005 and 2019 in EU28 countries. The yellow lines mark the change in the trading periods in the EU ETS.

Source: EUTL 2020, UN 2020

- ▶ Between 2005 and 2012, emissions decreased in all analysed countries except for Poland, where emissions increased by 20 % during this time period. Since 2013, emissions have decreased in all analysed countries except for Poland, where the emissions stayed roughly constant between 2013 and 2017. France shows the highest reduction in GHG emissions both from 2005 to 2012 as well as from 2013 to 2017 (-31 % respectively -12 %). In some countries (e.g. Germany), facilities that generate electricity for refineries were assigned to the activity “combustion installations” before 2013, whereas since 2013, they are assigned to activity 21 (“refining of mineral oil”). Emissions have therefore been at a higher level since 2013 than before and the data from 2013 on is not directly comparable with the time period 2005 until 2012.

2.2 Refinery throughput, refinery capacity and capacity utilization

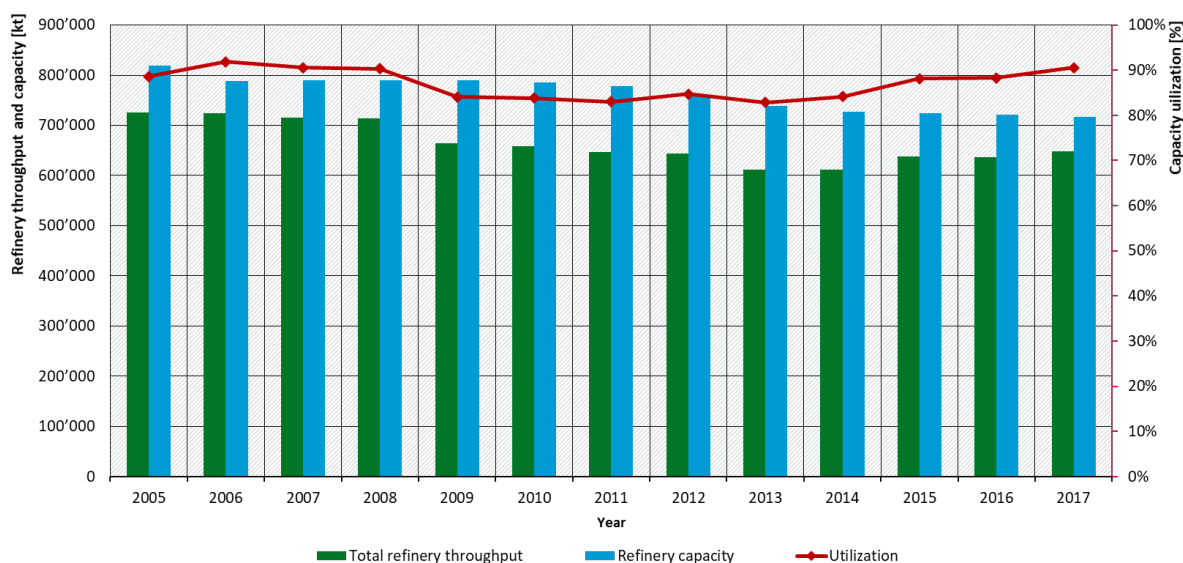
2.2.1 Definitions

- ▶ Refinery throughput: is equal to the sum of “transformation in refineries” for conventional crude oil, feedstocks, other hydrocarbons, additives and oxygenates, and natural gas liquids.
- ▶ Refinery capacity: the theoretical maximum capacity of crude oil distillation plants available for operation at the end of the reference year.
- ▶ Capacity utilization: corresponds to the ratio between throughput and refinery capacity.

2.2.2 Results

- ▶ The refinery throughput of the EU28 decreased from about 725 million tonnes in 2005 to about 648 million tonnes in 2017 (-10.6%). The throughput continuously decreased until 2014, when it reached its lowest level with roughly 612 million tonnes (UN 2020). Since then, the throughput increased again by about 6 % between 2013 and 2017. The refinery throughput increased in all analysed countries during this time period after it substantially decreased from 2005 to 2012 in most of the analysed countries (especially in Germany, France and Italy). In Spain and Poland, the throughput increased between 2005 and 2012 (+2 % respectively +40 %). The highest increase between 2013 and 2017 was observed in Spain (+9 %).
- ▶ The refinery capacity was at about 819 million tonnes in 2005 and dropped to 716 million tonnes in 2017 (-12.6%). Capacity utilization (i.e. the ratio between throughput and refinery capacity) increased slightly from 88.6% to more than 90% in 2017 (UN 2020).

Figure 5: Refinery throughput, refinery capacity and capacity utilization in the EU28



Evolution of total refinery throughput and total refinery capacity in the EU28 (2005-2017) (left axis). The red line (right axis) indicates the capacity utilization (i.e. throughput divided by total capacity) in the EU28.

Source: UN 2020, own calculations

The trend in the refinery capacity between 2013 and 2017 of selected countries is shown in the following table. An increasing trend is observed for the Netherlands and Spain and a decreasing trend for Germany, Italy and France. For Poland no change is observed in this time period.

Table 3: Trend in refinery capacity (2013-2017)

	Unit	Germany	Italy	Spain	France	Netherlands	Poland
Trends in refinery capacity (2013-2017)	%	-7%	-10%	11%	-7%	11%	0%

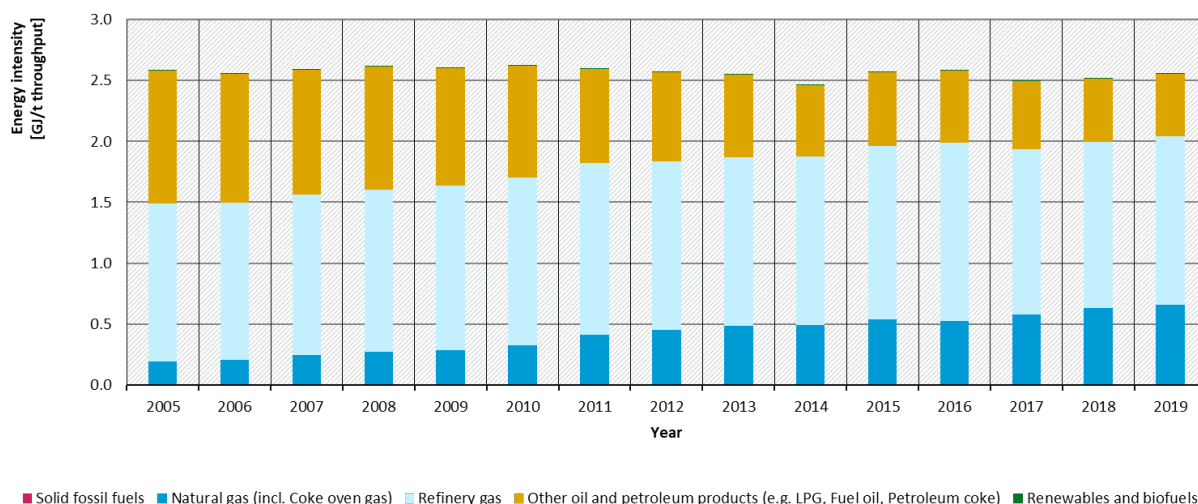
Source: UN 2020.

2.3 Evolution of energy intensity and share of energy carriers

The energy intensity of the petroleum refining plants is to a large extent determined by the composition of the fuels used in the refining process.

- ▶ Energy input in the refining industry is provided by Eurostat (Eurostat 2022a). It provides data on refinery consumption of solid fossil fuels, natural gas and other gases like coke oven gas, refinery gas and other oil and petroleum products like LPG, fuel oil and petroleum coke. Further, also consumption data of renewables and biofuels are provided.
- ▶ The energy intensity per tonne of refinery throughput in the EU28 is derived from the energy input according to Eurostat 2022a and related refinery throughputs according to the Energy statistics of the United Nations Statistics Division (UN 2020). It shows a rather constant development over time with a slight decreasing trend from 2005 (2.58 GJ/t) until 2019, reaching a level of 2.56 GJ/t throughput in 2019 (-0.8%).
- ▶ The energy input from natural gas (including coke oven gas) was constantly increasing between 2005 and 2019. In 2019, natural gas contributes a share of roughly 26 % in total energy intensity. In 2015, the share was only 7%.
- ▶ Other oil and petroleum products are also decreasing accounting for a share of 42% to 20%.
- ▶ Refinery gas accounts for the highest share of total energy input in the EU28 throughout the entire time period (50-57%).
- ▶ Other energy carriers such as solid fossil fuels and renewables and biofuels account for a negligible share of total energy input throughout the entire time period (<0.2%).
- ▶ With regard to the increasing consumption of natural gas, the six countries considered in this report all show a similar development. In most countries a strong shift from liquid fuels to natural gas, with the exception of the Netherlands, which exhibits already in 2005 a rather high share of natural gas.

Figure 6: Energy intensity of the petroleum refining industry and share of energy carriers in the EU28



Source: UN 2020, Eurostat 2022a

Energy intensity of the petroleum refining industry of selected countries in 2017 is shown in Table 4.

Table 4: Selected Member States: Energy and emission intensity of the petroleum refining industry in 2017

Unit	Germany	Italy	Spain	France	Netherlands	Poland
Emission intensity [t CO ₂ eq/t throughput]	0.23	0.24	0.21	0.17	0.17	0.15
Energy intensity [GJ/t crude oil]	2.8	2.1	3.0	1.8	1.4	1.7

Key figures of the petroleum refining industry in 2017 in the analysed countries.

Source: EUTL 2020, UN 2020, Eurostat 2022a

There can be many reasons for differences in national emission and energy intensities, deviations from the EU average and for changes over time, which should be subject to future, more detailed research on the installation level. One possible reason for differences between the national emission intensity values may be a different attribution of emissions to industry activities in EU ETS. For instance, in some member states emissions from electricity production for refineries may be attributed to the refinery industry (activity 21), but to combustion installations (activity 20) in other member states. The emission intensity value calculated in this report does also not take into account different product ranges. A change in emission intensity can also be due to changes in the energy input (i.e. substitution of liquid fuels by natural gas, see **Figure 6**), changes in the output (e.g. a switch from gasoline to diesel) and closure of refineries, which can also affect average emission intensities, since each refinery has a different emission intensity, depending on the range of products. Based on the energy intensity shown here, no conclusion can be drawn on energy efficiency of the refining plants.

2.4 Drivers of greenhouse gas emissions development in the petroleum refining industry

GHG emissions from the petroleum refining industry can be abated by different mitigation measures, such as increasing energy efficiency, substitution of liquid/solid fuels by gaseous fuels, selection of crude oil type, or investing in less emission intensive technologies such as biorefineries. CCS is currently not available at the relevant scale (Lukach 2015).

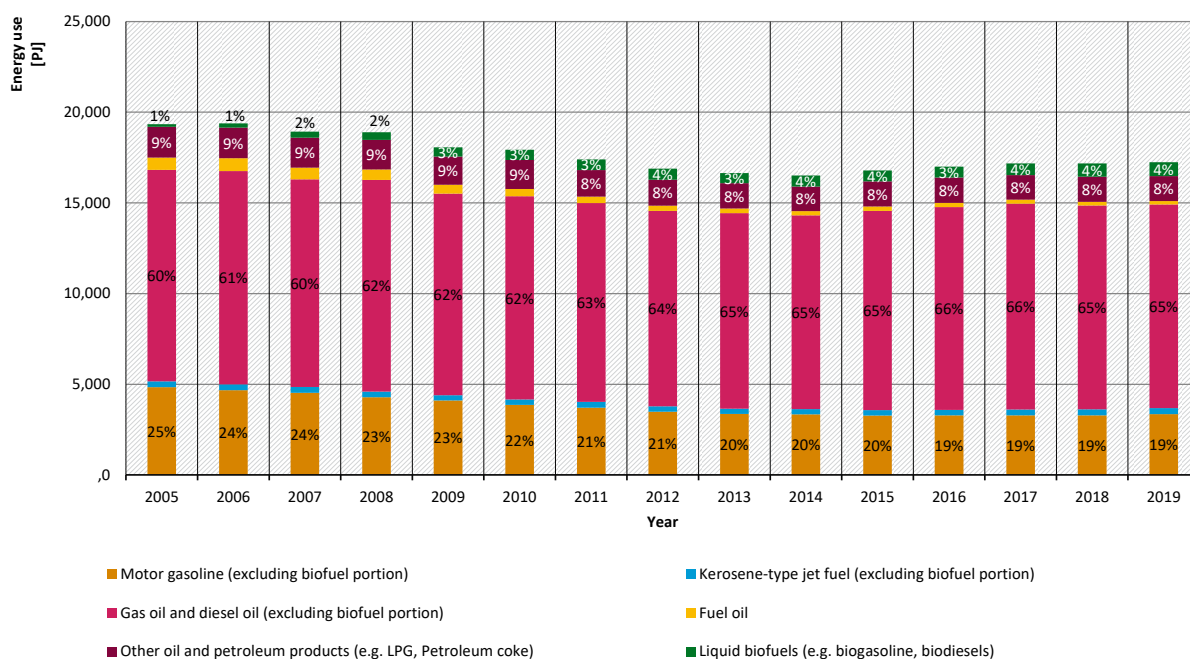
In addition, external factors influence emissions from the petroleum refining industry such as the regulatory framework in the EU as well as the demand of refined petroleum products.

2.4.1 Final consumption of oil products

- ▶ There is a decreasing trend in the demand for oil products in many countries of the EU since around 2007. Overall, demand for oil products in the EU28 decreased by about 11% from 19,400 PJ in 2007 to 17,000 PJ in 2019. There is however a slight increase since 2014 (+4%) (Figure 7). A similar trend was observed in an earlier study (UBA 2018).
- ▶ The development over time is driven by the consumption of oil and petroleum products like motor gasoline, gas oil and diesel oil as well as fuel oil, because these fuels account for the largest share of total demand. The consumption of these oil and petroleum products increased by roughly 2 % between 2013 and 2019. Compared to 2005, however, their consumption decreased by 14 % (Eurostat 2022b). There was a shift from fuel oil and motor gasoline to gasoil and diesel.
- ▶ A decreasing trend is observed mainly for the demand of fuel oil and gasoline in the EU28.
- ▶ Demand for diesel and gas oil as well as kerosene shows an increase since 2013 (Eurostat 2022b). For marine fuel oil, a substitution of fuel oil by gas oil is observed (FuelsEurope 2019).
- ▶ The share of liquid biofuels in the total energy use in the EU28 has strongly increased compared to 2005 and 2013 (Eurostat 2022b), from 1 % in 2005 to 4 % in 2017.
- ▶ In the road transportation sector, there was a shift from gasoline to diesel since around 2000 up to 2017⁵, leading to an overproduction of gasoline in the European petroleum refining industry and a subsequent increase in gasoline exports to countries outside of the EU (FuelsEurope 2019). The share of gas oil and diesel oil increased from 65% in 2013 to 66 % in 2017, while the share of motor gasoline decreased from 20% in 2013 to 19% in 2017.
- ▶ Consumption of diesel and gas oil is mostly covered by domestic production of the European refineries, whilst the demand of kerosene is covered by a substantial share (30% in 2017) of imports from Russia and Asia (FuelsEurope 2019).

⁵ Due to the diesel scandal, a reversing trend is observed after 2017.

Figure 7: Final consumption of oil products and share of energy carriers in the EU28



Source: Eurostat 2022b

2.4.2 Biofuels

A few petroleum refining plants in Italy and in France were converted to biorefineries since 2014 (see appendix).

- ▶ In Italy, there are currently two biorefineries in operation, one in Venice and another one in Gela, Sicily.
- ▶ In France, the petroleum refining plant “Raffinerie de Provence” in La Mède owned by TOTAL Raffinage France was converted into a biorefinery in 2015 and went into operation in 2019. It produces both biodiesel and bio-jet fuel for the aviation industry and processes vegetable oils as well as animal fats, cooking oil etc.

The increase in demand of biofuels (i.e. biodiesel, bioethanol) leads to a substitution of fossil diesel and gasoline in the transport sector (see **Figure 7**).

2.4.3 Complexity of the refining process (measure: Nelson Index)

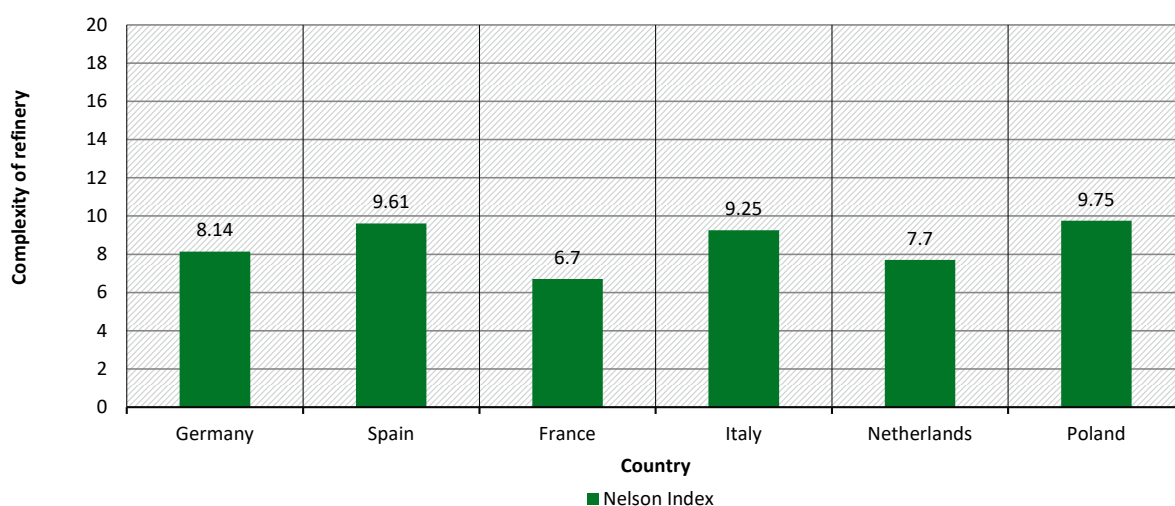
Generally, the production of lighter and more valuable products requires more processing (needs higher complexity of the refining process) and therefore results in higher GHG emissions. The complexity of the refining process therefore has a strong impact on the GHG emission levels, however at the national level, no correlation between the Nelson index and the emissions of the refining plants is observed.

- ▶ The Nelson Index is a measure of the complexity of a refinery in terms of the types of petroleum products it can produce. The index ranges from 1 to 20, with the more complex refineries having higher values. Complex refineries are able to produce lighter, more refined and valuable products, such as gasoline and kerosene, and their construction and maintenance are more costly (Investopedia 2021). **Figure 8** shows the average Nelson index

per country. It is calculated based on the available data at the facility level by weighting the index with its capacity.⁶ However, at the national level, the Nelson Index (**Table 2**) does not correlate with greenhouse gas emissions of the refining plants.

- ▶ Poland has the highest average Nelson Index with 9.75 followed closely by Spain with 9.61. The country with the lowest average Nelson Index is France (6.7).
- ▶ The Nelson index does not seem to have a strong impact on the GHG emissions of the refining industry at the national level. As already described (see chapter 2.3), the fact that emissions from electricity generation for refineries are not uniformly attributed to the refinery industry (activity 21), but in some member states to combustion installations (activity 20) probably plays a role here. Possible correlations should be further investigated at the plant level.

Figure 8: Capacity weighted Nelson Index of countries



Capacity weighted average Nelson Index of the refineries in Germany, Spain, France, Italy, the Netherlands, and Poland.
Source: abarrelfull 2020

⁶ Data are available for each country, however not for all facilities within a country (abarrelfull 2020).

2.4.4 Type of crude oil (measure: Atmospheric Residue)

The characteristics and composition of the type of crude oil used in the refining process have impacts on emission levels. The central part of the petroleum processing is the distillation. The part of the crude oil product that is not distilled under normal pressure is called the Atmospheric Residue (AR). It is the feed product for the subsequent vacuum distillation. According to Jess and Kern (2009), a larger AR indicates higher GHG emissions from refining this type of crude oil. The following table shows the atmospheric residue of crude oil from different countries (Jess and Kern, 2009). The table covers types of crude oil that are typically used in the refining industry of Germany.

Table 5: Atmospheric residue of different types of crude oil processed in Germany

Import region	Share of crude oil processed in Germany (in weight percent)	Atmospheric residue
	%	%
Middle East	6.7	47
Africa	18.5	45
EU	13.8	43
Norway	16.9	34
Venezuela	1.5	75
CIS	42.6	42
Weighted average		42.1

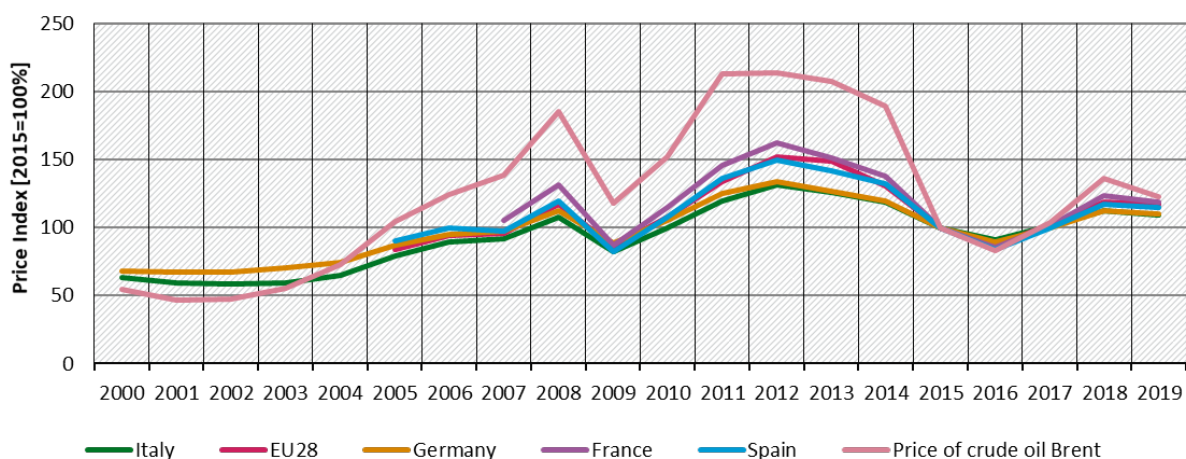
Source: Jess, A. and C. Kern (2009)

- ▶ The atmospheric residue is one of the factors affecting energy intensity of the refining process. Spain and Italy import some crude oil from Venezuela (<4% of imports) with a high atmospheric residue, indicating a higher emissions intensity of the refining of this type of crude oil. Germany, Poland and the Netherlands import some of the crude oil from Norway (<10 %), which contributes to a lower emissions intensity in the refineries processing this type of crude oil with a low atmospheric residue.
- ▶ As most of the crude oil is imported from countries that do not show large differences in terms of the atmospheric residue (i.e. Africa, EU, GUS), the influence of the AR on GHG emissions from the refining sector is of minor importance in the countries considered in the present report.

2.4.5 Producer price of refined petroleum products

- ▶ In all countries investigated in the present report, the producer price of refined petroleum products (i.e. the selling price received by domestic producers for their output) shows a strong increase between 2005 and 2008 followed by a sharp drop between 2008 and 2009. Between 2009 and 2012, the prices were increasing and then dropping again until 2016. Since then, prices are increasing again (Eurostat 2020d).
- ▶ Since 2005 the trend in the producer price index in Italy, Germany, France and Spain is very similar to the trend of the EU average (Eurostat 2020d). Deviations from the average of EU are due to differences in the share of specific petroleum products across different countries.
- ▶ The Brent crude oil price follows a similar trend as the producer price of refined petroleum products, as it is the main input of the refining process.

Figure 9: Evolution of the producer price of refined petroleum products and of the price of crude oil Brent



Evolution of the producer price of refined petroleum products in Italy, Germany, France, Spain and the EU28 and of the price of crude oil Brent from 2000 – 2019. The prices are indexed, 2015 is 100 %. For the EU and Spain, data are available only since 2005. For France only since 2007. There is no data on the producer price for Poland and the Netherlands in this time period.

Source: Eurostat 2020d

2.4.6 Conclusion

- ▶ The main driver of the observed evolution of GHG emissions from the refining industry between 2005 and 2017 is the declining **demand for petroleum products**, such as gasoline as well as light and heavy fuel oil. Apart from Poland, all investigated countries show a declining trend in the demand of oil and petroleum products since 2005. There is however a slight increase since 2014 of the consumption of oil productions (+4%).
- ▶ The shift in demand for certain products is of great importance for the emissions: The share of gas oil and diesel oil increased while the share of motor gasoline and fuel oil decreased between 2013 and 2019. In addition, in the transport sector there is some substitution of fossil fuels by biofuels. These changes could explain the decreasing GHG emissions of the refinery sector between 2013 and 2017 while consumption increased.

- ▶ The **capacity weighted average Nelson index** (see definition in section 2.4.3) does not seem to have a strong impact on the GHG emissions of the refining industry at the national level. Possible correlations should be further investigated at the plant level.
- ▶ **Atmospheric residue:** As most of the crude oil is imported from countries that do not show large differences in terms of the atmospheric residue (i.e. Africa, EU, GUS), the influence of the atmospheric residue on GHG emissions from the refining sector is of minor importance in the countries considered in the present report.

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A Appendix: Facility data of selected countries

This section gives an overview on the EU ETS refining industry in selected countries on a facility level. It contains emissions and production capacities of the three largest plants per country and a map with the location of all EU ETS refineries (as of 2019).

A.1 Germany

The following table provides an overview on GHG emission and refinery capacity of the three largest refining plants in Germany.

Table 6: Germany: Emissions and production capacity of the three largest petroleum refining plants

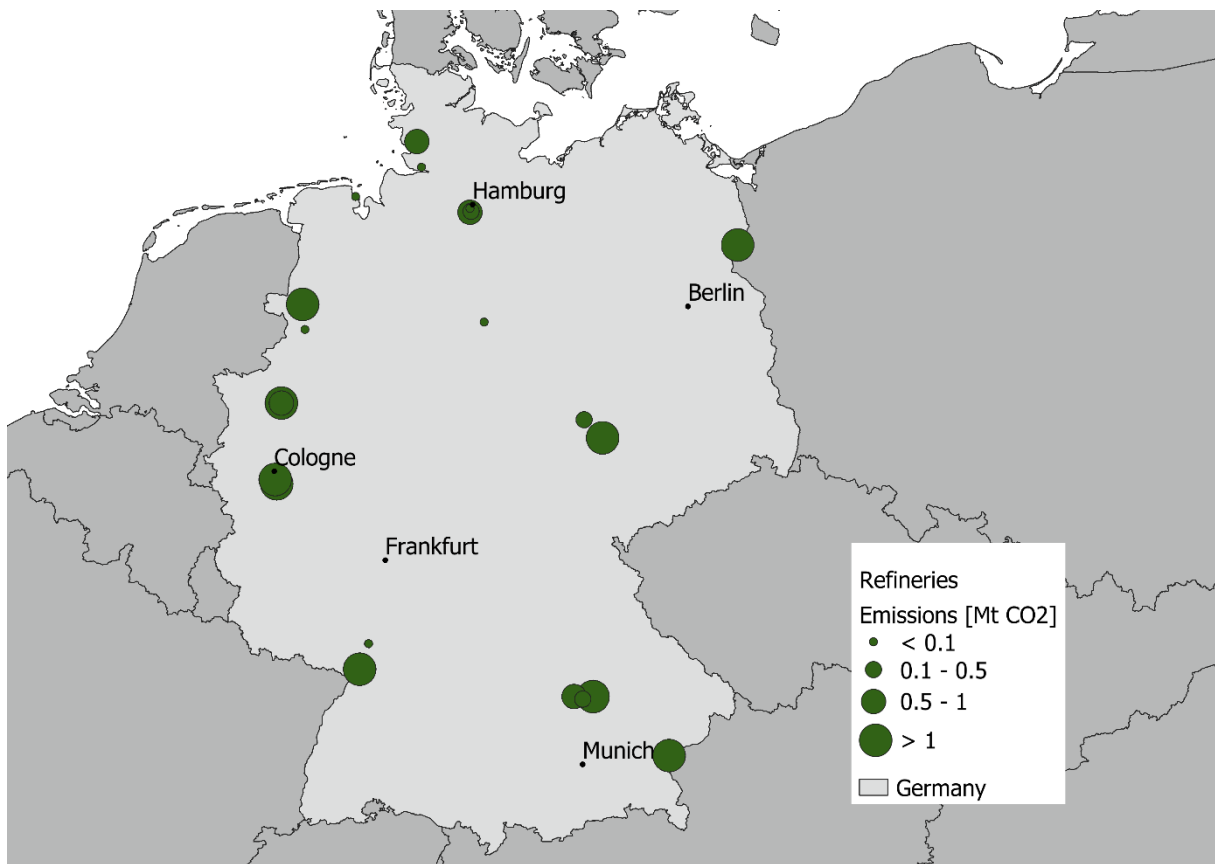
ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions	Share of total capacity
				2005	2010	2013	2015	2019	2019	2019
19	PCK Raffinerie Glocke Schwedt	PCK Raffinerie GmbH	Schwedt	1.5	1.5	3.6	4.0	3.4	15.7%	8.4%
3	RUHR OEL GmbH - Werk Scholven - CO ₂ -Glocke	Ruhr Oel GmbH	Gelsenkirchen	3.8	3.7	3.5	3.2	3.0	13.8%	11.4%
12	Werk 1 und Werk 2	Mineralöl-raffinerie Oberrhein GmbH & Co. KG	Karlsruhe	0.6	0.8	2.9	2.4	2.7	12.2%	11.4%

Source: EUTL 2020, UN2020

- ▶ In 2019, 22 petroleum refining plants were in operation.
- ▶ The three refining plants with highest emissions account for roughly 42 % of total verified emissions from the petroleum refining sector.

The following map shows the location of the petroleum refining plants participating in the EU ETS in 2019 in Germany. 9 plants emitted over 1 million tonnes of CO₂, four facilities emitted between 500,000 and 1 million tonnes of CO₂ and 9 facilities had emissions below 500,000 tonnes in 2019.

Figure 10: Germany: Map of petroleum refining plants in 2019



Location of petroleum refining plants in Germany (2019), the size of the dots indicates the amount of verified emissions in 2019.

Source: EUTL 2020

A.2 Italy

The following table provides an overview on GHG emission and refinery capacity of the three largest refining plants in Italy.

Table 7: Italy: Emissions and production capacity of the three largest petroleum refining plants

ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions	Share of total capacity
				2005	2010	2013	2015	2019	2019	2019
575	Impianti di raffinazione	Sarlux Srl	Sarroch (Cagliari)	6.3	6.2	5.9	6.6	6.1	35.1 %	14.7 %
180	Raffineria di Sannazaro	ENI S.P.A.	Sannazaro de' Burgondi	2.1	2.3	2.4	2.8	2.4	14.0 %	8.8 %
541	Raffineria di Milazzo	Raffineria di Milazzo S.C.p.A.	Milazzo	1.8	1.8	1.8	1.9	1.7	10.1 %	7.9 %

Source: EUTL 2020, UN2020

- ▶ In 2019, 15 petroleum refining plants were in operation.
- ▶ The three refining plants with highest emissions account for roughly 59 % of total verified emissions from the petroleum refining sector.
- ▶ Two refineries were converted to biorefineries (Raffineria di Venezia in 2014, Raffineria di Gela S.P.A. in 2019). The one in Venice is the first conventional refinery in the world to be converted into a biorefinery. They mainly process raw biomaterials such as plant-based oils, animal fats, used cooking oils or algae extracts. By 2023, there should also be no more palm oil used but rather alternative inputs such as waste from plant-oil processing and waste oils. At the Venice plant, HVO (Hydrotreated Vegetable Oil) biofuel is produced. Through a 'Waste to fuel' technology, also bio-oil will be produced to be used as a low-sulphur fuel for maritime transport. At the Gela plant, biodiesel, bio-naphtha, bio-LPG and bio-jet fuel are produced (ENI 2021).
- ▶ In 2019, these refineries still participated in the EU ETS (sector 21 Refining of mineral oil), due to the conventional petrochemical plants that were still in operation. However, their emissions are at a very low level. The emissions from these two plants decreased from 4.3 million tonnes in 2005 to around 0.4 million tonnes in 2019 (EUTL 2020).

A.3 Spain

The following table provides an overview on GHG emission and refinery capacity of the three largest refining plants in Spain.

Table 8: Spain: Emissions and production capacity of the three largest petroleum refining plants

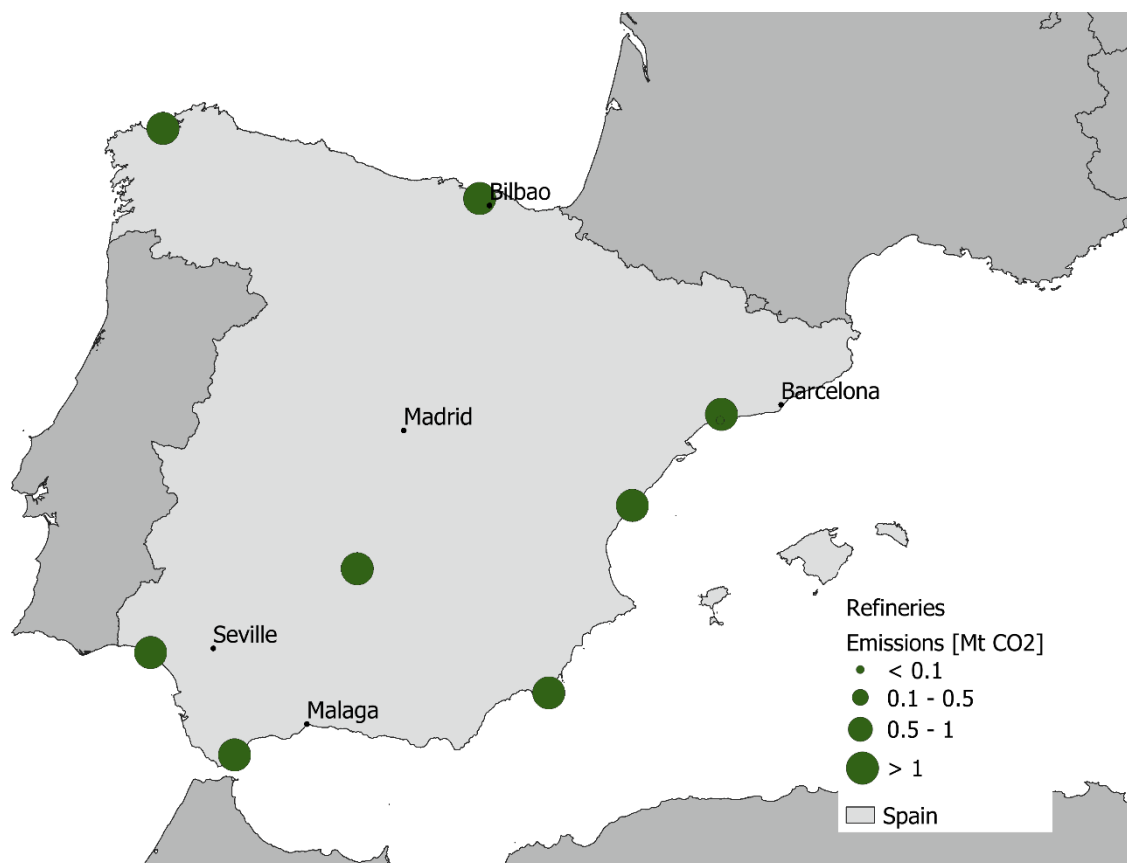
ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions	Share of total capacity
				2005	2010	2013	2015	2019	2019	2019
736	Repsol Petróleo S.A.	Repsol Petróleo, S.A.	Cartagena (Murcia)	0.7	0.5	2.4	2.5	2.4	17.5 %	14.5 %
797	Petróleos del Norte S.A.	Petróleos del Norte, S.A.	Muskiz (Vizcaya)	2.2	2.0	2.3	2.3	2.1	15.7 %	14.5 %
476	Repsol Petróleo S.A. – Instalación de Tarragona	Repsol Petróleo, S.A.	La Pobla de Mafumet (Tarragona)	2.8	2.6	2.2	2.3	2.1	15.6 %	12.3 %

Source: EUTL 2020, UN2020

- ▶ In 2019, 10 petroleum refining plants were in operation.
- ▶ The three refining plants with highest emissions account for almost 50% of verified emissions from the petroleum refining sector.

The following map shows the location of the petroleum refining plants participating in the EU ETS in 2019 in Spain. 8 plants emitted over 1 million tonnes of CO₂ and two facilities had emissions below 500,000 tonnes in 2019.

Figure 12: Spain: Map of petroleum refining plants in 2019



Location of petroleum refining plants in Spain (2019), the size of the dots indicates the amount of verified emissions in 2019.

Source: EUTL 2020

A.4 France

The following table provides an overview on GHG emission and refinery capacity of the three largest refining plants in France.

Table 9: France: Emissions and production capacity of the three largest petroleum refining plants

ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions	Share of total capacity
				2005	2010	2013	2015	2019	2019	2019
253	Raffinerie de Normandie	Total Raffinage France	Harfleur	3.0	3.4	2.9	2.7	2.4	25.3 %	18.5 %
259	Esso Raffinage SAF	Esso Raffinage	Notre Dame de	2.7	2.1	2.0	1.9	2.0	20.8 %	20.8 %

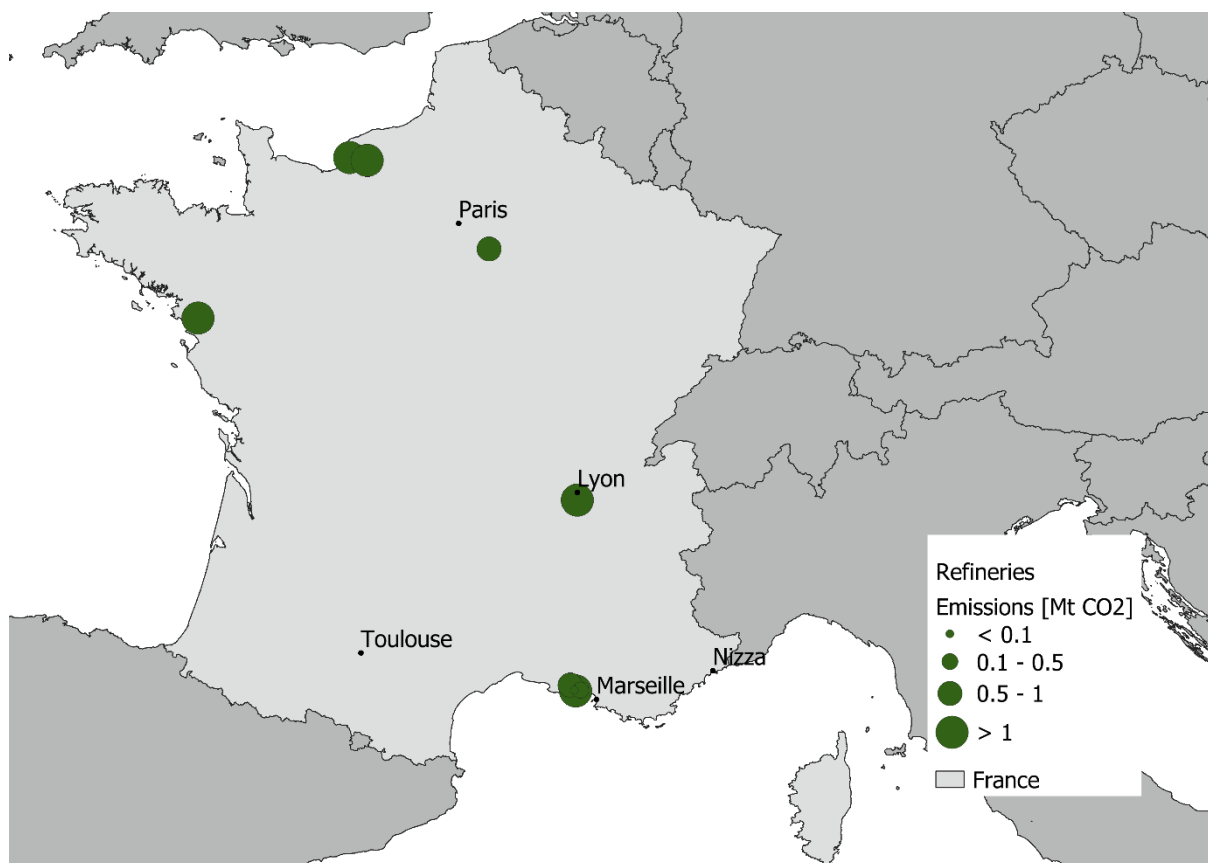
ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions	Share of total capacity
			Gravenchon							
614	Raffinerie de Lavera	Petroineos Manufacturing France SAS	Lavera	1.5	1.2	1.3	1.3	1.4	14.7 %	1.5 %

Source: EUTL 2020, UN2020

- ▶ In 2019, 10 petroleum refining plants were in operation.
- ▶ The three refining plants with highest emissions already account for more than 60 % of total verified emissions from the petroleum refining sector in France.
- ▶ One refinery (Raffinerie de Provence in La Mède) was converted to a biorefinery. With the transformation of the plant in La Mède, France's first biorefinery was created (TOTAL 2019). It produces both biodiesel and biojet fuel for the aviation industry and processes vegetable oils as well as animal fats, cooking oil etc. instead of conventional crude oil (TOTAL 2015, 2019). Since 2018, this refinery no longer participates in the EU ETS (sector 21 Refining of mineral oil) and shows a strong reduction of GHG emissions of the petroleum refining sector between 2005 and 2019 (EUTL 2020).

The following map shows the location of the petroleum refining plants participating in the EU ETS in 2019 in France. 5 plants emitted over 1 million tonnes of CO₂, two facilities emitted between 500,000 and 1 million tonnes of CO₂ and three facilities had emissions below 500,000 tonnes in 2019.

Figure 13: France: Map of petroleum refining plants in 2019



Location of petroleum refining plants in France (2019), the size of the dots indicates the amount of verified emissions in 2019.

Source: EUTL 2020

A.5 The Netherlands

The following table provides an overview on GHG emission and refinery capacity of the three largest refining plants in the Netherlands.

Table 10: Netherlands: Emissions and production capacity of the three largest petroleum refining plants

ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions 2019	Share of total capacity 2019
				2005	2010	2013	2015	2019		
99	Shell Nederland Raffinaderij B.V.	SHELL Nederland Raffinaderij B.V.	Hoogvliet - Rotterdam	5.8	4.1	4.4	4.3	4.4	39.2 %	35.9 %

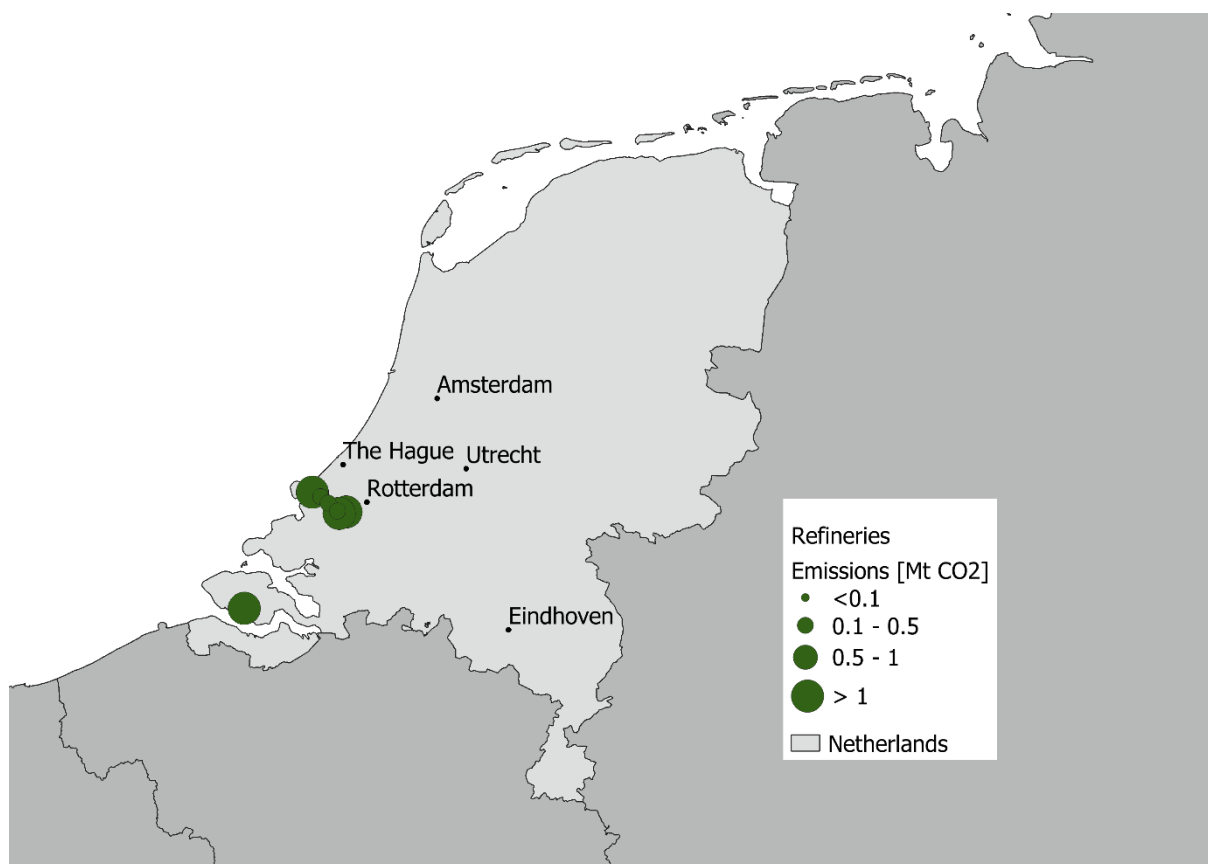
ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions	Share of total capacity
96	Esso Raffinaderij Rotterdam	Esso Nederland B.V.	Botlek-Rotterdam	2.2	2.2	2.0	2.3	2.4	21.4 %	16.8 %
98	BP Raffinaderij Rotterdam B.V.	BP Raffinaderij Rotterdam B.V.	Europoort-Rotterdam	2.0	2.2	2.0	2.3	2.2	19.4 %	34.5 %

Source: EUTL 2020, UN2020

- ▶ In 2019, 7 petroleum refining plants were in operation.
- ▶ The three refining plants with highest GHG emissions in 2019 already account for 80 % of total verified emissions from the petroleum refining sector in the Netherlands.

The following map shows the location of the petroleum refining plants participating in the EU ETS in 2019 in the Netherlands. 4 plants emitted over 1 million tonnes of CO₂ and three facilities had emissions below 500,000 tonnes in 2019.

Figure 14: Netherlands: Map of petroleum refining plants in 2019



Location of petroleum refining plants in the Netherlands (2019), the size of the dots indicates the amount of verified emissions in 2019.

Source: EUTL 2020

A.6 Poland

The following table provides an overview on GHG emission and refinery capacity of the three largest refining plants in Poland.

Table 11: Poland: Emissions and production capacity of the three largest petroleum refining plants

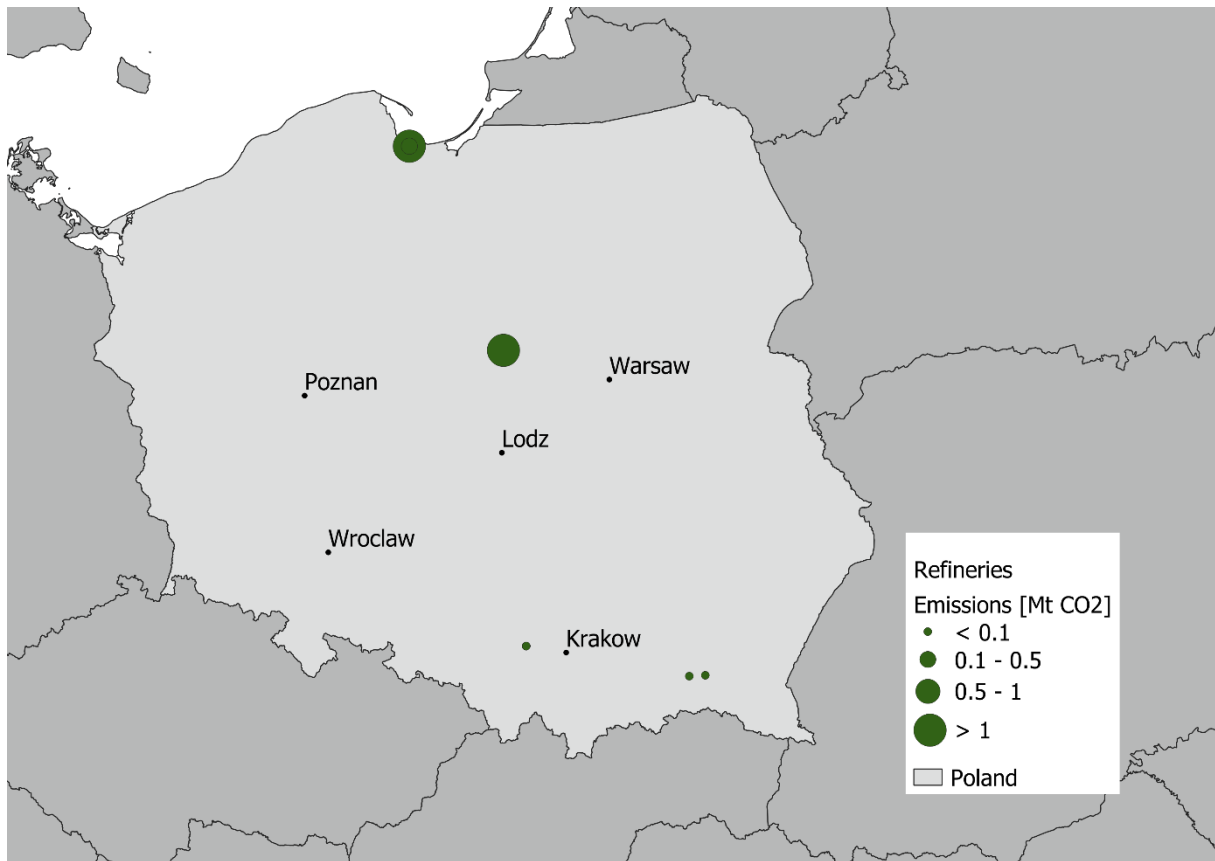
ID	Installation	Company	City	Emissions (Mt CO ₂)					Share of total verified emissions	Share of total capacity
				2005	2010	2013	2015	2019	2019	2019
362	Rafineria	Polski Koncern Naftowy ORLEN S.A.	Plock	2.5	2.0	2.5	2.6	2.8	62.7 %	54.4 %
361	Instalacje Rafinerijne	Grupa Lotos S.A.	Gdansk	0.7	0.7	1.4	1.6	1.5	32.8 %	41.4 %
648	Instalacja Rafinerijna Lotos Asphalt Gdansk	Lotos Asphalt sp. z o.o.	Gdansk	0.01	0.01	0.01	0.01	0.17	3.8 %	2.4 %

Source: EUTL 2020, UN2020

- ▶ In 2019, 7 petroleum refining plants were in operation.
- ▶ The three refining plants with highest emissions account for 99.3 % of verified emissions from the petroleum refining sector.

The following map shows the location of the petroleum refining plants participating in the EU ETS in 2019 in Poland. Two plants emitted over 1 million tonnes of CO₂ and 5 facilities had emissions below 500,000 tonnes in 2019.

Figure 15: Poland: Map of petroleum refining plants in 2019



Location of petroleum refining plants in Poland (2019), the size of the dots indicates the amount of verified emissions in 2019.

Source: EUTL 2020