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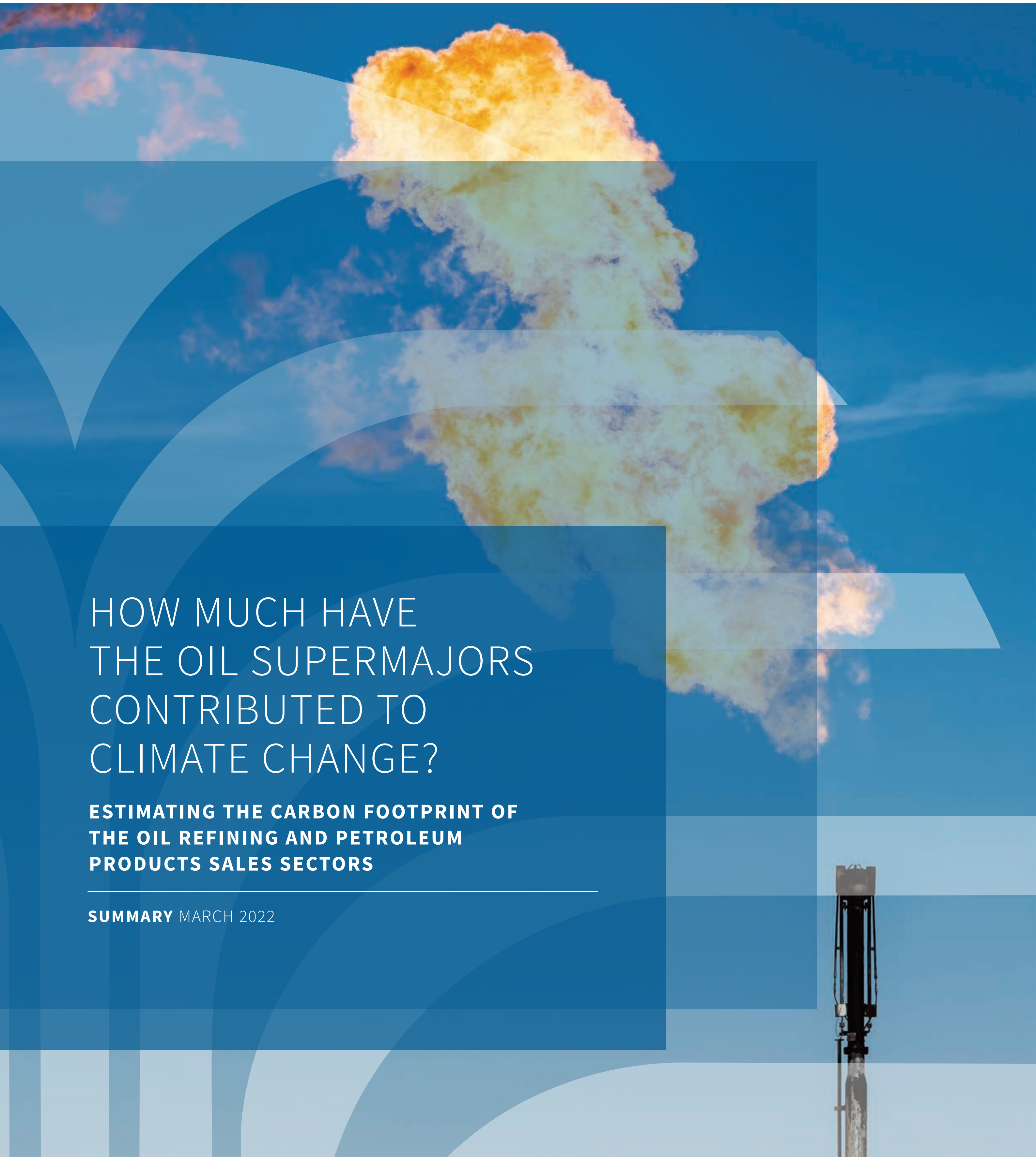

HOW MUCH HAVE THE OIL SUPERMAJORS CONTRIBUTED TO CLIMATE CHANGE?

ESTIMATING THE CARBON FOOTPRINT OF THE OIL REFINING AND PETROLEUM PRODUCTS SALES SECTORS

SUMMARY MARCH 2022

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS 3
SUMMARY 4
INTRODUCTION 6
PART I. METHODOLOGY 8
1.1. Methodology 8
1.2. Stages and Boundaries 10
1.3. Life-cycle Emission Factors 10
PART II. CARBON FOOTPRINT OF THE PETROLEUM PRODUCTS SALES SECTOR AND THE OIL REFINING SECTOR 12
2.1. Carbon Footprint of the Petroleum Products Sales Sector 12
2.1.1. Supermajors 13
2.2. Carbon Footprint of the Oil Refining Sector 13
2.2.1. Supermajors 13
2.3. Comparison Between the Oil Refining Sector and the Petroleum Products Sales Sector 15
CONCLUSION 19
REFERENCES 21

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LIST OF ACRONYMS AND ABBREVIATIONS

AIC	Akaike information criterion
API	American Petroleum Institute
BOE	Barrels of Oil Equivalent
BUR	Biennial Update Reports
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EPA	U.S. Environmental Protection Agency
EIA	U.S. Energy Information Administration
FCC	Fluid catalytic cracking
GHG	Greenhouse gas
GOR	Gas-to-oil ratio
GREET	Greenhouse Gases, Regulated Emissions, and Energy use in Transportation
GWP	Global Warming Potential
H_2	Hydrogen
H_2O	Water
IPCC	Intergovernmental Panel on Climate Change
IPIECA	International Petroleum Industry Environmental Conservation Association
JV	Joint Venture
LPG	Liquefied petroleum gas
M	Million
M&A	Merger and Acquisition
Mt	Million metric tonnes
NHSTA	National Highway Traffic Safety Administration
NIR	National Inventory Report
OCI	Oil-Climate Index
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
OPEM	Oil Products Emissions Module
OPGEE	Oil Production Greenhouse Gas Emissions Estimator
PRELIM	Petroleum Refinery Life Cycle Inventory Model
SOR	Steam oil ratio
UNFCCC	United Nations Framework Convention on Climate Change
VFF	Venting, flaring, and fugitives
WOR	Water-to-oil ratio
WRI	World Resources Institute

SUMMARY

In the 40-year period 1980–2019, annual carbon dioxide (CO_2) emissions from fossil fuel combustion, including flaring, increased by more than 80%, and total emissions from those sources represented approximately 83% of anthropogenic CO_2 emissions (also including cement production and land-use change) without accounting for sinks. Understanding the carbon footprint of countries and companies along the oil value chain is fundamental to outlining paths to reduced reliance on fossil fuels. However, academic analyses of carbon footprints are limited by the lack of a reliable dataset and carbon accounting method that would allow comparisons across countries and companies.

A pioneering 2014 upstream-focused study by Richard Heede quantified the historical contribution of the "carbon majors" to global CO_2 and methane (CH_4) emissions from 1751 to 2010, tracing 63% of cumulative global emissions to 90 upstream fossil fuel companies (including oil, gas, and coal) and cement companies. A focus on their extraction-based activities does not offer insights into the full scale of their hold on oil value chains. This paper sheds light on their contribution to emissions from the midstream and downstream levels of the value chain.

Our study estimates the global carbon footprint of the oil refining and petroleum sales sectors, adopting a supply-chain approach. The study also assesses the life-cycle greenhouse gas emissions from the oil refining and petroleum products sales businesses of the "Oil Supermajors"—BP, Chevron, Eni, ExxonMobil, Shell, and TotalEnergies—the six largest publicly traded oil companies by revenue and political influence.

Using a mix of quantitative methods and open-source models, we first estimate a time series (1980–2019) of country-specific life-cycle greenhouse gas emission factors for the sectors of crude oil refining and sales of petroleum products refined from crude oil (gasoline, jet fuel, diesel, fuel oil, residual fuels, and LPG), without accounting for gas value chains, for the 83 countries that jointly accounted for 93% of the global crude oil refining throughput in 2015. We then estimate the global and country-level carbon footprints of the two sectors based on the emission factors we estimated, global refinery outputs, and sales volume. Applying our life-cycle model to data on refinery output and sales of petroleum products, we estimate the supermajors' carbon footprints in both sectors. These carbon footprints are not meant to be added up as they overlap.

The petroleum products sales sector sold approximately 1,128 billion barrels of petroleum products from 1980 to 2019, leading to emissions of approximately 508 metric gigatons of carbon dioxide equivalent (Gt CO_2e). The sector's global carbon footprint nearly doubled in the 40-year period. The six supermajors jointly account for 35% of the cumulative global carbon footprint of the sector in the same period, evidencing that they own a sizeable share of the sector.

The oil refining sector refined approximately 985 billion barrels of crude oil from 1980 to 2019, leading to emissions of approximately 443 Gt CO_2e. The sector's global carbon footprint increased by approximately 51% in the 40-year period. The supermajors jointly account for approximately 23% of the cumulative global carbon footprint of the sector in the same period, reflecting lower but still significant market concentration.

The carbon intensities of the companies are within a narrow range, which largely results from the interconnectedness of the value chains. The supermajors refined and sold petroleum products originating from crude oil extracted by other companies. For instance, the oil used for more than 50% of Shell's sold products comes from third parties. When Shell sells these petroleum products, the carbon embedded in them comes from multiple oil fields associated with different values of API gravity, refinery efficiency, and distribution distance. The API gravity of Shell's typical oil fields as well as the impact of Shell's refinery efficiency and distribution network is diluted in a portfolio of API gravity, refinery efficiency, and distribution distance values associated with oil coming from other companies.

The report also scrutinizes companies' emissions accounting methods and concludes that company numbers rely on various and not fully transparent reporting boundaries, volume, and emission accounting methodologies. Most problematic is that most supermajors fail to report scope 3 emissions comprehensively; there is also a lack of time-series data on scope 3 emissions. In addition, the volume and emission accounting method might underestimate emissions in three ways: by omitting the emissions of third parties in the company's value chain (e.g. when a company sells petroleum products produced and refined by other companies or when it refines products later sold by other companies), playing with boundaries, or omitting data from non-operated joint ventures.

While our estimation addresses some limitations of company emissions reporting, our methodological approach still presents its own limitations, attesting to the lack of data transparency and standardized carbon accounting at both country and corporate level, which prevents informed decision-making on those holding the levers of influence on companies: investors, consumers, and policy makers. Without consistent and transparent emission accounting, companies' net-zero commitments and targets are meaningless. To address these limitations, the Coalition on Material Emissions Transparency (COMET), supported by the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC), will create a harmonized greenhouse gas calculation framework applicable to all mineral and industrial supply chains.

INTRODUCTION

Fossil fuel combustion, including flaring, accounts for approximately 68% of cumulative global anthropogenic emissions of carbon dioxide (CO_2), the most prominent greenhouse gas (GHG) causing global warming. Between 1980 and 2019 alone, the 40-year period of study in this report, annual CO_2 emissions from those sources increased by more than 80%, and total emissions from those sources represented approximately 83% of anthropogenic CO_2 emissions (also including cement production and land-use change) without accounting for sinks[1] (Global Carbon Project 2021). Understanding the carbon footprint of countries and companies along the oil value chain is fundamental to understanding the paths to reduced reliance on fossil fuels. However, academic analysis of carbon footprints to date has lacked a reliable set of data and a reliable carbon accounting method that allows comparisons across countries and companies.

Indeed, developing and applying such a method poses various challenges. For long, academic literature focused more on calculating the carbon footprint of individual market segments along the oil value chain than on estimating the life-cycle carbon footprint of petroleum products (Gordon et al. 2015). Only in 2011 did the World Resources Institute (WRI) release an internationally accepted accounting standard under the GHG Protocol (Gillenwater 2015) to calculate scope 3 emissions, defined as emissions from sources that the reporting entity does not own or directly control (Bhatia et al. 2011). In addition, certain Non-Annex I countries,[2] such as China and Saudi Arabia, are crucial crude oil refining and consuming countries but have less standardized emission reporting than Annex I countries (Heede 2014).[3] As a result, there is a lack of time-series data for scope 3 emissions from the oil industry, and the understanding of the GHG emissions attributable to the oil refining and petroleum sales segments of the oil value chain is currently underdeveloped.

In a pioneering attempt to address these issues, Heede (2014) quantified the historical contribution of the "carbon majors"[4] to global CO_2 and methane (CH_4) emissions from 1751 to 2010. The study traces 63% of cumulative global emissions to 90 upstream fossil fuel companies (including oil, gas, and coal) and cement companies.

Differently from Heede's (2014) extraction-based analysis, our study estimates the global carbon footprint of the oil refining and petroleum sales sectors adopting a supply-chain carbon-footprint approach. We leverage existing open-source academic models, but extend their time series and increase the number of countries covered. In addition, our study focuses on assessing the life-cycle GHG emissions from the oil refining and petroleum products sales businesses of the "supermajors"—BP, Chevron, Eni, ExxonMobil, Shell, and TotalEnergies—the six largest publicly traded oil companies by revenue and political influence.[5]

For the avoidance of doubt, this study neither adopts a scope-based approach nor addresses the accounting challenges of such an approach. Our study assesses life-cycle GHG emissions: all emissions released throughout the value chain of a barrel of oil, from upstream exploration to final combustion. In addition to a company's own value chain emissions, this method enables us to estimate the emissions from barrels of oil that the company refined or sold, including oil extracted by other companies.

Using a mix of quantitative methods, we first estimate a time series of country-specific life-cycle GHG emission factors for the sectors of crude oil refining and sales of petroleum products[6] refined from crude oil, covering the period 1980–2019 and including 83 countries. We then estimate the global and country-level carbon footprints of the oil refining and petroleum products sales sectors based on the emission factors we derived, global refinery outputs, and sales volume. Finally, we estimate the share of the six supermajors in those footprints, using their sales volumes, refinery outputs, and operating locations.

This paper summarizes the CCSI study "How Much Have the Oil Supermajors Contributed to Climate Change? The Carbon Footprint of The Oil Refining and Petroleum Products Sales Sectors – Full Report."[7]

FOOTNOTES

1 Sinks include oceans and forests as well as cement carbonation, which absorb and capture CO_2 from the atmosphere and reduce its atmospheric concentration.

2 The 160 Non-Annex I Parties to the UNFCCC (most of them developing countries) are not required to submit National Inventory Reports (NIRs) every year but must submit Biennial Update Reports (BURs), including a national inventory report and information on mitigation actions.

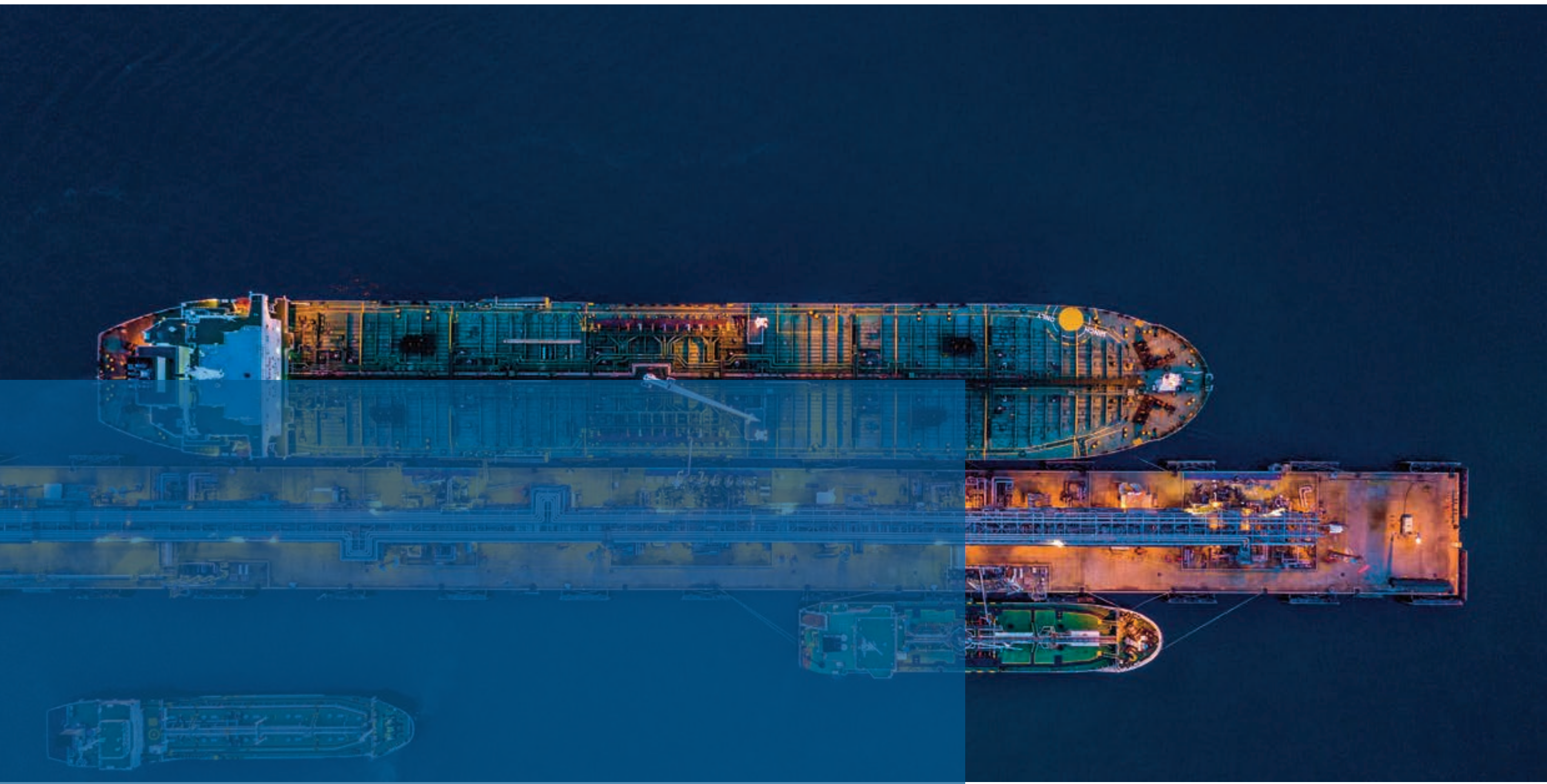
3 Annex I Parties include Organisation for Economic Co-operation and Development (OECD) countries plus other developed countries and economies in transition.

4 Fossil fuel companies that produced more than 8 million metric tons of carbon per year.

5 The first four originated from a group of seven companies known as "Seven Sisters" (BP, Chevron, ExxonMobil, Shell, Gulf, and Texaco) (Anthony 1976); after successive mergers and acquisitions, the Seven Sisters are now four of the so-called supermajors group. Eni and TotalEnergies have also been considered supermajors (Statista 2021). ConocoPhillips is only seldom included in the list of supermajors since it spun off its downstream operations (OilNow 2017).

6 The petroleum products studied in this paper are gasoline, jet fuel, diesel, fuel oil, residual fuels, and LPG refined from crude oil.

7 Jiarui Chen, Perrine Toledano, and Martin Dietrich Brauch, *How Much Have the Oil Supermajors Contributed to Climate Change? The Carbon Footprint of The Oil Refining and Petroleum Products Sales Sectors* (New York: Columbia Center on Sustainable Investment [CCSI], March 2022).



PART 1
METHODOLOGY

1.1. METHODOLOGICAL STEPS

The broad methodological steps followed in this paper are described as follows. The full report describes the methodology in greater detail.

1. We gather production data, including volume, carbon intensity, API gravity,[9] sulfur in the sectors of crude oil refining and sales of petroleum products refined, from crude oil in the selected 83 countries from the supplementary information of the research paper by Jing et al. (2020), which builds on Wood Mackenzie (2015). The dataset covers 93% of the global crude oil refining throughput in 2015 and is therefore representative of the global oil refining sector. Emissions from fossil gas are not within the scope of this study. Emissions from products other than crude oil in the upstream industry, such as petrochemicals and lubricants, are also not within the scope of this study.[10]

2. We build our estimation model on three open-source models that are commonly used in academic papers: (1) the Oil Production Greenhouse Gas Emissions Estimator (OPGEE) Model to estimate upstream emission factors (El-Houjeiri and Brandt 2017), (2) the Petroleum Refinery Life Cycle Inventory Model (PRELIM) to estimate mid-stream emission factors (Abella, Motazedi, and Bergerson 2015), and (3) the Oil Products Emissions Model (OPEM) to estimate downstream emission factors (Gordon 2016). We also refer to the Oil-Climate Index (OCI) Model to aggregate life-cycle emission factors (Gordon et al. 2015) and the Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) Model to obtain parameters for deriving time-series emission factors (Cai, Sykora, and Wang 2021).
3. We break down life-cycle GHG emission factors by the upstream, midstream, and downstream oil sectors following the stages and boundaries defined in Section 1.1,[11] setting up the framework to estimate GHG emission factors. The framework includes the stages of emissions in each sector, emission sources, determining factors,[12] formulas, and default emission factors.
4. For each sector of the oil value chain (upstream, midstream, and downstream), we assess the statistical significance of certain factors to GHG emission factors by running univariate regressions for each of these determining factors. Since the regression results reveal that API gravity is statistically significant in determining the emission factors of most stages of the three sectors of the oil value chain,[13] we adopt API gravity as the determining factor to estimate country-specific emission factors. The 83 countries in our sample are "destination countries"[14] (Jing et al. 2020) and, for this reason, are given the API gravity characterizing the crude oil they are importing to feed their refineries.
5. For each stage of the value chain, we estimate country-specific emission factors by applying the decision-tree model, a machine learning model that predicts results by categorical independent variables. The model learns relationships between API gravity and other stage-specific parameters in the OCI sample, which then enables us to extrapolate the relationship in the context of the 83 countries.
6. To estimate the change in upstream emission factors throughout time, we use the 25-year change of emission factors of representative oil fields (Masnadi and Brandt 2017). We also estimate the change in Vented, Flaring, and Fugitive (VFF) emissions[15] in the upstream sector based on the time-series change of VFF emission factors in the United States. We estimate the change in midstream emission factors throughout time based on the time-series change of API gravity and sulfur content in the United States. We also derive the time-series change of default emission factors calculated by the U.S. Environmental Protection Agency (EPA) to update the parameters in model estimation and adjust the change in emission factors in the three sectors throughout time.
7. We compute life-cycle emission factors for each country and over time by summing up the emission factors throughout the three stages of the oil value chain.
8. To assess the supermajors' contribution to GHG emissions, we first collect data on refinery output, petroleum products sales, and geographic distribution of sales of the six supermajors, based on corporate reports and commercial databases. We apply our life-cycle emission factors to the data on the companies' oil refining and petroleum products sales by country and year to estimate the carbon footprint of their oil refining and petroleum products sales sectors. These two types of carbon footprints are separate and not cumulative.

FOOTNOTES

8 American Petroleum Institute (API) gravity is a measure of a petroleum liquid's density relative to that of water (Ernest, et al. 1959).

9 Sulfur content is expressed as the percentage of sulfur in crude oil, which is a measure of its purity.

10 For instance, the OPGEE model doesn't include GHG emissions from condensates of light liquids that can be separated and sold before oil is transported to a refinery or emissions from co-products like petcoke that are associated with upgrading heavy oils upstream of the refinery.

11 We consider the stages of emissions in each sector as commonly defined by government agencies (the U.S. Environmental Protection Agency [EPA]), intergovernmental organizations (the Intergovernmental Panel on Climate Change [IPCC]), industry associations (the American Petroleum Institute [API]), and academic literature.

12 Factors that determine the GHG emissions, including oil field characteristics, production techniques, crude oil grades, refinery configuration, transportation modes, etc. (as explained in the following sections).

13 API is statistically significant to the production, drilling, and processing stage in the upstream sector and to total refining emissions and product types in the downstream sector.

14 Destination countries/regions represent the locations where refined products are sold. Thus, the data takes into account the import/export of refined products when calculating transportation from the refining sector to the petroleum products sale sector.

15 VFF emissions include emissions from leaks, venting, and flaring associated with onshore and offshore crude oil exploration, production, and transportation to and from refineries (emissions from refineries are removed from our emission factors for the upstream stage) (U.S. Environmental Protection Agency 2021).

1.2. STAGES AND BOUNDARIES

As per the OCI model (Gordon et al. 2015), we define in Table 1 the stages and the activities within each stage in our life-cycle model.

All activities within the oil value chain are allocated into one of these 12 stages; we therefore cover the entire oil value chain, without overlap between stages. The emission factor associated with each stage only covers the emissions of the specific stage, eliminating the risk of double counting.

1.3. LIFE-CYCLE EMISSION FACTORS

Summing up emission factors at all stages, we create a time series of life-cycle emission factors from 1980 to 2019 for the 83 countries. Life-cycle emission factors vary by country due to the variance in crude oil grades, refinery configuration, and transportation. Figure 1 shows the life-cycle emission factors by country in 2015, ranging from Denmark's 469.55 kg CO_2e/bblCrude to Uzbekistan's 624.13 kg CO_2e/bblCrude. The emission factors also vary over time due to technological evolution, and the aging and replacement ratio of oil fields.

The downstream sector accounts for the largest share of life-cycle emission factors, which is 85.91% on average over time, while the midstream sector accounts for 7.95% and the upstream sector, for 6.22% (see Figure 2). Our estimated data is similar to that of the OCI dataset, which is 83.81% for OPEM downstream emission factors, 10.78% for OPGEE upstream emission factors, and 5.41% for PRELIM midstream emission factors[16] (Gordon et al. 2015).

TABLE 1: STAGES AND BOUNDARIES OF THE LIFE-CYCLE MODEL

SECTOR	STAGE	ACTIVITIES WITHIN STAGE
Upstream	Exploration	Clearing land, seismic survey and drilling exploratory wells
	Drilling & development	Drilling production wells, installing equipment
	Production & extraction	Lifting fluids and injecting fluids, flooding, gas flooding, steam flooding
	Surface processing	Seperating the fluids into streams of oil, gas and water
	Maintenance	Maintaining compressors, wells, and pipelines
	Waste Disposal	Disposing waste produced in upstream operations
	Transport to refinery	Transporting cruide oil from upstream production facility to refinery
Midstream	Separation	Piping crude oil through hot furnaces, discharging liquids and vaports, seperating liquids and vapors into different petroleum components
	Conversion	Processing low-value petroleum components into higher-value petroleum products
	Treatment	Making gasoline, diesel and kerosene
Downstream	Transport to retail	Transporting crude oil from refinery facility to retail market (gas station etc.)
	Combustion	Petroleum products used by end users

Source: Adapted from Gordon et al. (2015).

FOOTNOTES

16 We calculate the average percentage of each sector emission factors in the OCI dataset, weighting by production volume of 75 oil fields in "Oil Climate Index Webtool - Phase II" dataset (Gordon, et al. 2015).

FIGURE 1: LIFE-CYCLE EMISSION FACTORS BY COUNTRY IN 2015

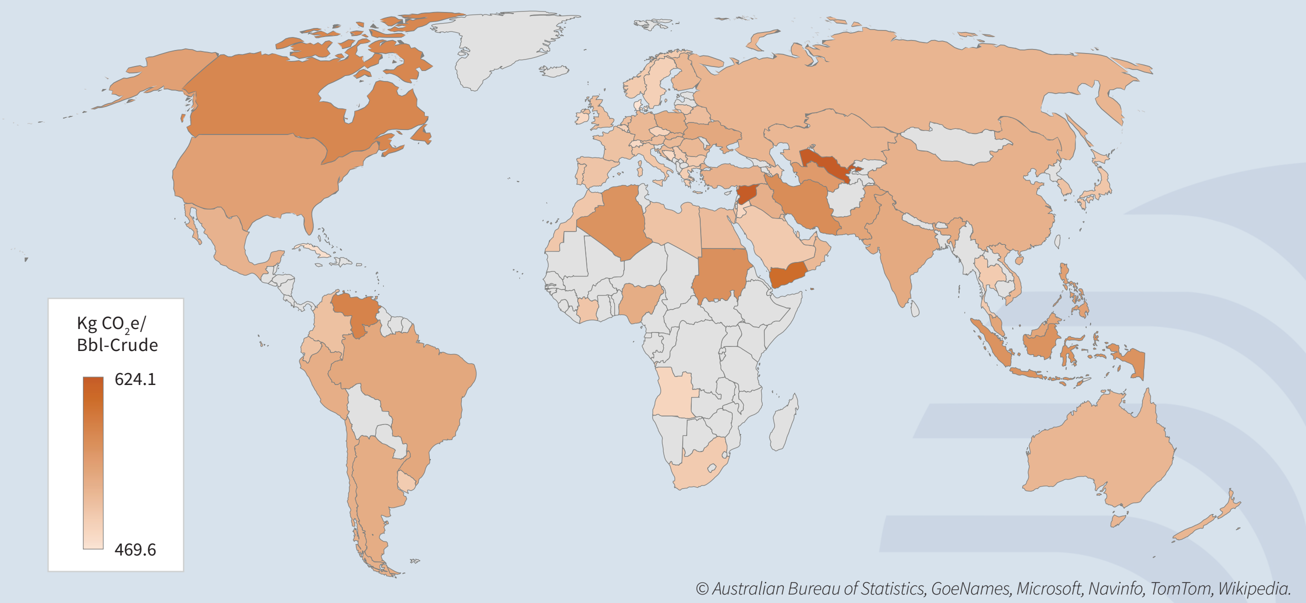
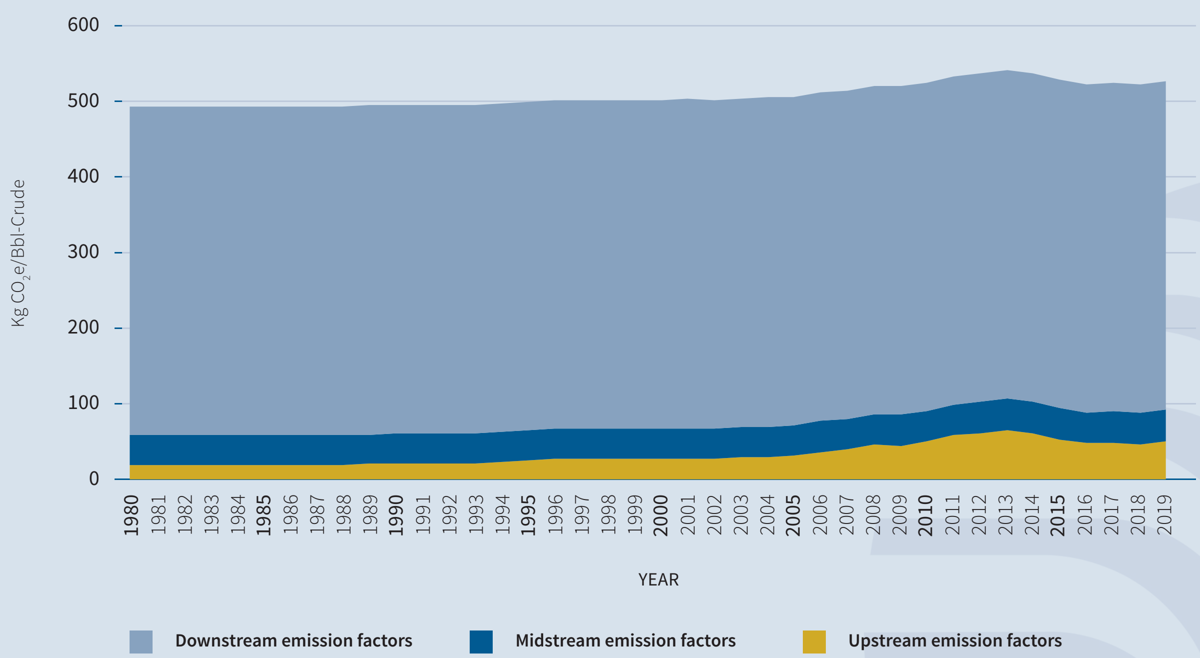


FIGURE 2: LIFE-CYCLE EMISSION FACTORS BY SECTORS WEIGHTED AVERAGE BY OIL CONSUMPTION



PART 2

CARBON FOOTPRINT OF THE PETROLEUM PRODUCTS SALES SECTOR AND THE OIL REFINING SECTOR

2.1. CARBON FOOTPRINT OF THE PETROLEUM PRODUCTS SALES SECTOR

The carbon footprint of the petroleum products sales sector (LPG, gasoline, diesel, jet fuel, kerosene, fuel oil, and residual oil) accounts for the CO_2 released during the sales operation as well as along the value chain of crude oil, which is referred to as the sum of scope 1, 2, and 3 emissions (Hertwich and Wood 2018). The sector is the final link in the oil value chain and the bridge connecting it to the end-users and, as such, has a crucial impact on the emissions from petroleum products. Global consumption of petroleum products is the source of combustion emissions, the largest share of life-cycle GHG emissions from oil.

Applying a life-cycle assessment, we trace the carbon footprint of petroleum products sold based on the destination country or region and the year of the sale, considering all associated emissions along the value chain and the variety of the refined products in terms of crude oil type, oil fields, refinery configuration, and transport. By assessing the carbon footprint of the sector, we quantify its share in GHG emissions as well as the GHG emissions from the combustion of petroleum products.[17]

Also, we incorporate the fact that some petroleum products are consumed but not combusted. They are used as construction materials, chemical feedstocks, lubricants, solvents, waxes, and other products (U.S. Energy Information Administration 2018). According to the literature, non-combusted petroleum products accounted for 13% of total petroleum products consumption in the United States in 2017 (U.S. Energy Information Administration 2018) and 13.9% in the European Union (EU) in 2019 (Eurostat 2021). Hence, we apply a 13.45% discount rate, which is an average of U.S. and EU non-combusted petroleum products consumption proportion, to the combustion emissions within the life-cycle carbon footprints for both the petroleum product sales sector and the refining sector.[18]

The petroleum products sales sector is highly concentrated. According to the data we collected, sales of petroleum products by the six supermajors account for 24.15% of global petroleum consumption.[19] By quantifying the supermajors' life-cycle carbon footprint in the sector, we focus on the major contributors to GHG emissions in the industry and determine their weights in the sector in terms of GHG emissions.

We first summarize the supermajors' sales data (volume of petroleum products sold in their wholesale and retail segments as reported in company financial reports, adjusting for the merger and acquisition [M&A] effect)[20] and the geographic distribution of their sales. We estimate the companies' carbon footprint by applying our life-cycle model to the data.

Large companies in the sector, including the six supermajors, have recently started to report their estimated scope 3 emissions. Even though we haven't adopted a scope-based approach, we compare the carbon footprint estimated under our model with the scope 1, 2, and 3 emissions reported by the companies, assess the boundaries of emissions reporting by different companies, and evaluate the completeness of their emissions reporting.

From 1980 to 2019, the global petroleum sales sector sold 1,128.06 billion barrels of petroleum products, leading to emissions of 508.43 metric gigatons of carbon dioxide equivalent (Gt CO_2e), according to our model. On average, the sector sold 28.20 billion barrels of petroleum products per year; to produce, process, refine, transport, and combust these products, the whole oil value chain released a yearly average of 12.71 Gt CO_2e, according to our model. The carbon footprint of the global sector nearly doubled from 1980 to 2019, which reflects the increasing trend of consumption of petroleum products.

2.1.1. Supermajors

From 1980 to 2019, the petroleum products sales segment of the supermajors is estimated to account for 178.11 Gt CO_2e released from the 400.59 billion barrels of petroleum products sold, which accounts for approximately 35% of the carbon footprint of the global petroleum products sales sector during 1980–2019.

2.2. CARBON FOOTPRINT OF THE OIL REFINING SECTOR

We multiply the 83 countries' refinery output by the corresponding country-specific life-cycle emission factors resulting from our model to estimate the carbon footprint of the refinery sector by country. For countries not included in our model, we apply the global average emission factors while acknowledging that this results in a simplification. Consolidating the carbon footprints of all countries, we estimate the carbon footprint for the global refining sector. From 1980 to 2019, the global sector refined approximately 984 billion barrels of crude oil, leading to emissions of approximately 443 Gt CO_2e. The carbon footprint of the global refining sector increased steadily over time by approximately 51% from 1980 to 2019, reflecting the increasing trend of oil extraction over the period of study.

2.2.1. Supermajors

From 1980 to 2019, the total refinery output of the supermajors was approximately 227 billion barrels, which accounts for 23.11% of the global refinery output during the period. Among the supermajors, ExxonMobil refined the biggest volume of crude oil (approximately 66 billion barrels), while Eni refined the smallest (approximately 11 billion barrels).

From 1980 to 2019, the refining segment of the supermajors is estimated to account for 101.22 Gt CO_2e released from the 227.52 billion barrels of petroleum products produced by refineries, which accounts for 22.86% of the carbon footprint of the global refining sector during 1980–2019 (see Figures 3 and 4).

FOOTNOTES

17 We assume that all petroleum products are combusted.

18 We did not estimate the emissions from the variable fractions of plastics, tires, lubricants, waxes, and other non-energy products that are combusted in post-consumer use.

19 The data sources include: global consumption of petroleum products from 1980 to 2019 (U.S. Energy Information Administration 2021); companies' crude oil production from 1980 to 2018 (Climate Accountability Institute 2020); BP volume of sales of petroleum products from 2008 to 2019 (Bloomberg LP 2021a); geographic distribution of BP's revenue (Bloomberg LP 2021a); Chevron supplementary annual reports (Chevron 2011; Chevron 2016; Chevron 2020; Chevron 2021); companies' petroleum products production data from Refinery Report in Oil & Gas Journal (2019); Eni fact books (Eni 2012; Eni 2015; Eni 2018; Eni 2020a; Eni 2020b; Eni 2021); ExxonMobil Financial & Operating Review (ExxonMobil 2005; ExxonMobil 2010; ExxonMobil 2014; ExxonMobil 2018; ExxonMobil 2021a; ExxonMobil 2021b; ExxonMobil 2021c; ExxonMobil 2021d); ExxonMobil's petroleum products sales segment by destination country for 2000–2019 (Bloomberg LP 2021b); Shell investors' handbook (Shell 2012; Shell 2015; Shell 2020); TotalEnergies fact books (TotalEnergies 2007; TotalEnergies 2010; TotalEnergies 2015; TotalEnergies 2020b); BP statistics (2020); companies' refining capacity in 2020 from McKinsey Refinery Capacity Database (Fitzgibbon 2020).

20 We adjusted for the M&A effect between oil companies, adding time-series data of acquired companies to the merged companies.

FIGURE 3: ANNUAL CARBON FOOTPRINTS OF THE SUPERMAJORS' REFINING & PETROLEUM PRODUCTS SALES SEGMENTS 1980–2019

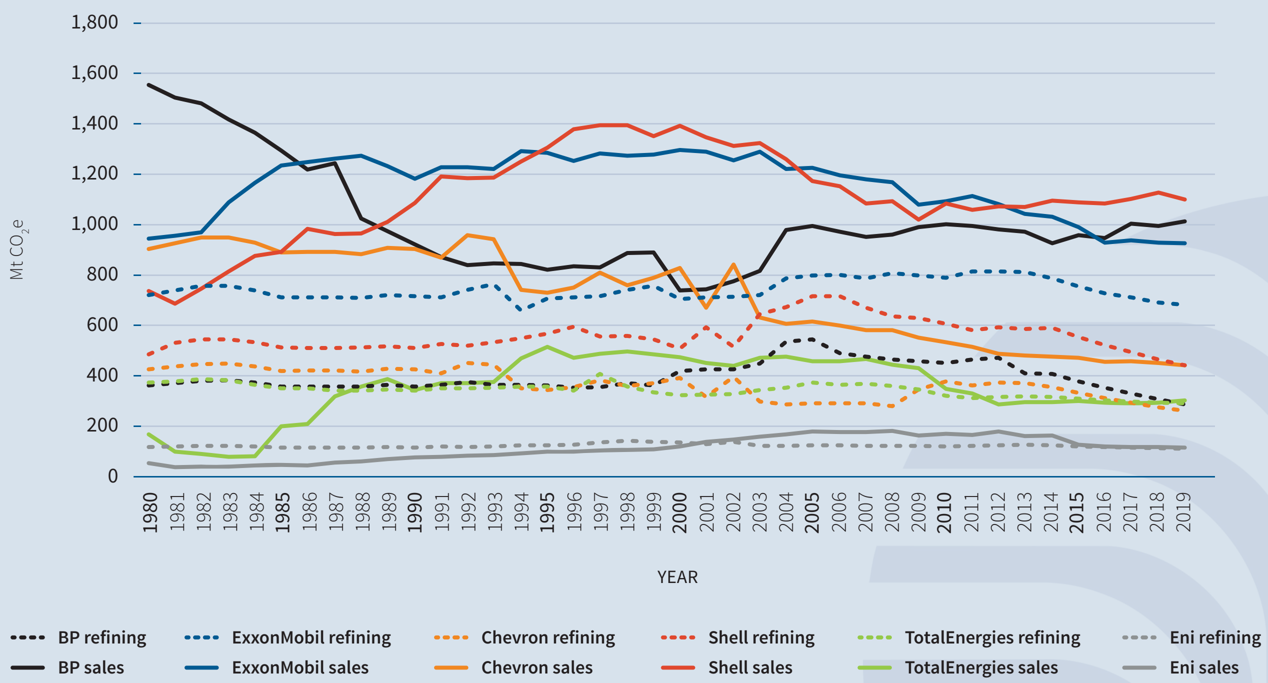
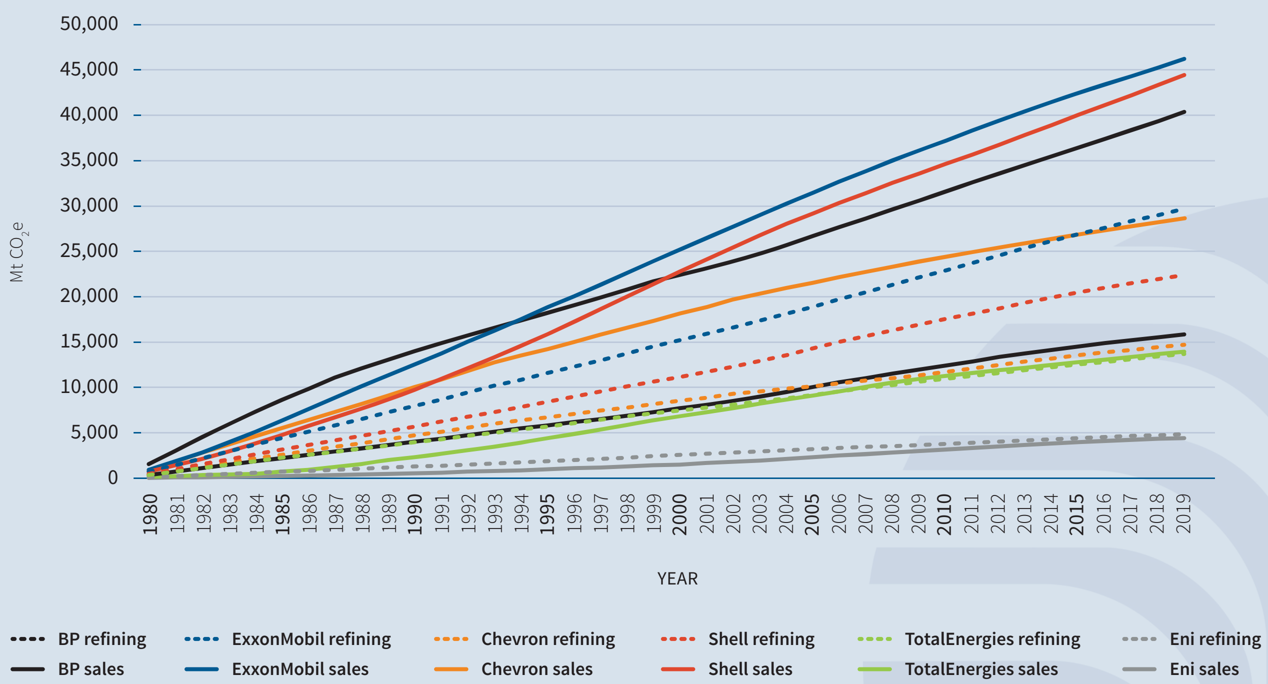


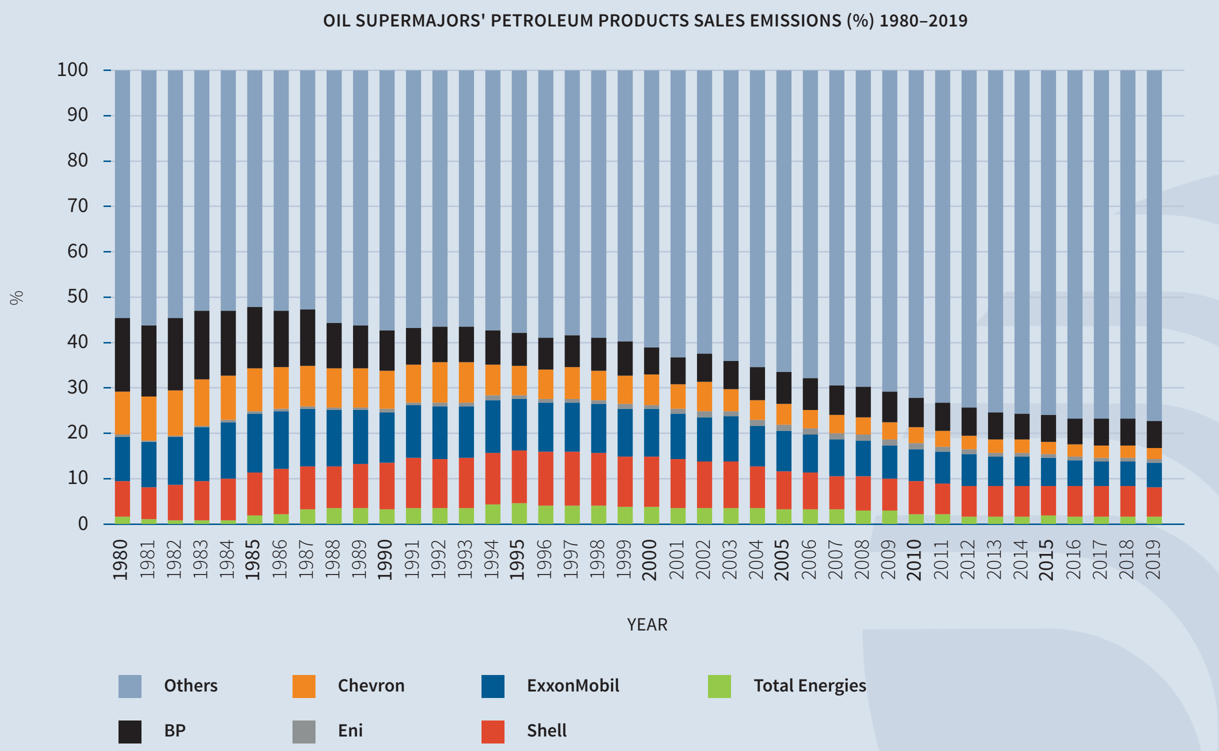
FIGURE 4: CUMULATIVE CARBON FOOTPRINTS OF THE SUPERMAJORS' REFINING & PETROLEUM PRODUCTS SALES SEGMENTS 1980–2019



2.3. COMPARISON BETWEEN THE OIL REFINING SECTOR AND THE PETROLEUM PRODUCTS SALES SECTOR

Compared with the petroleum products sales segment, the refining segment of the supermajors accounts for a smaller proportion of the global carbon footprint (approximately 23% vs. approximately 35%), which reveals that the refining sector is less concentrated. In terms of individual companies, the supermajors' petroleum products sales segment has a larger carbon footprint than their refining segment (see Figures 5 and 6). This difference is aligned with the reality that big oil companies hold bigger market shares of the downstream market than of the refining market.

FIGURE 5: EMISSIONS FROM THE SUPERMAJORS' PETROLEUM PRODUCTS SALES SEGMENTS, 1980–2019



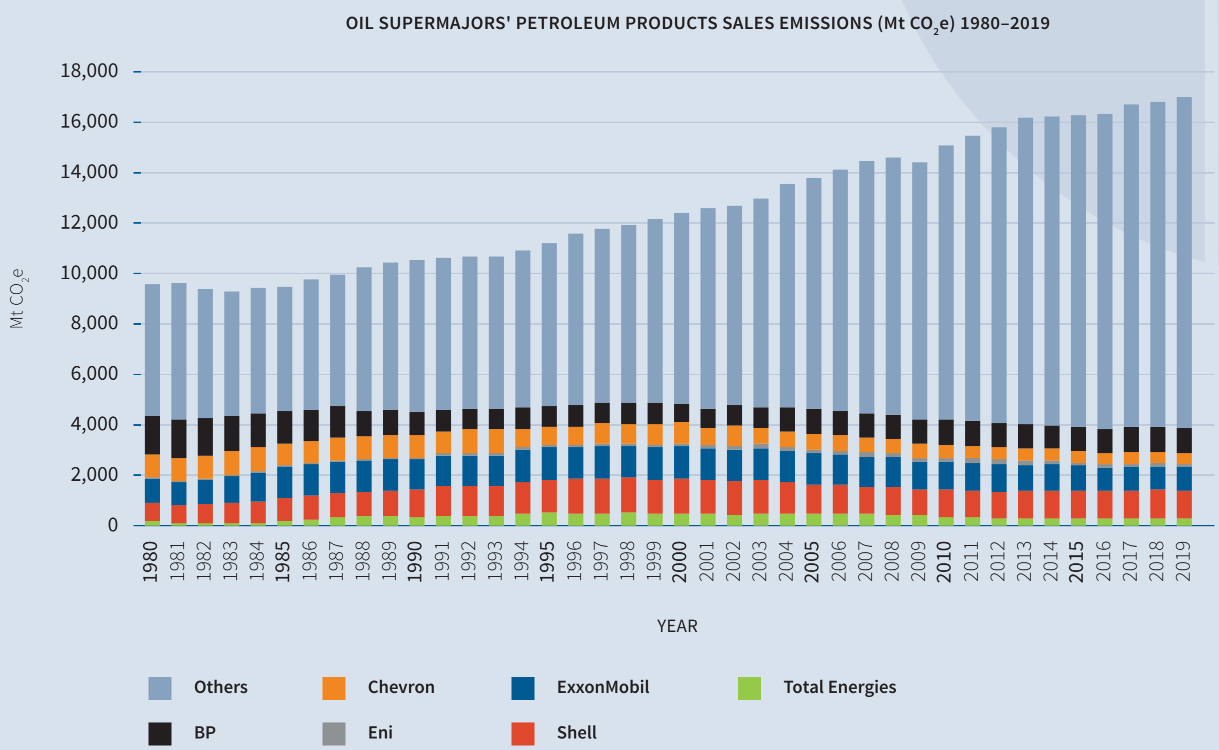
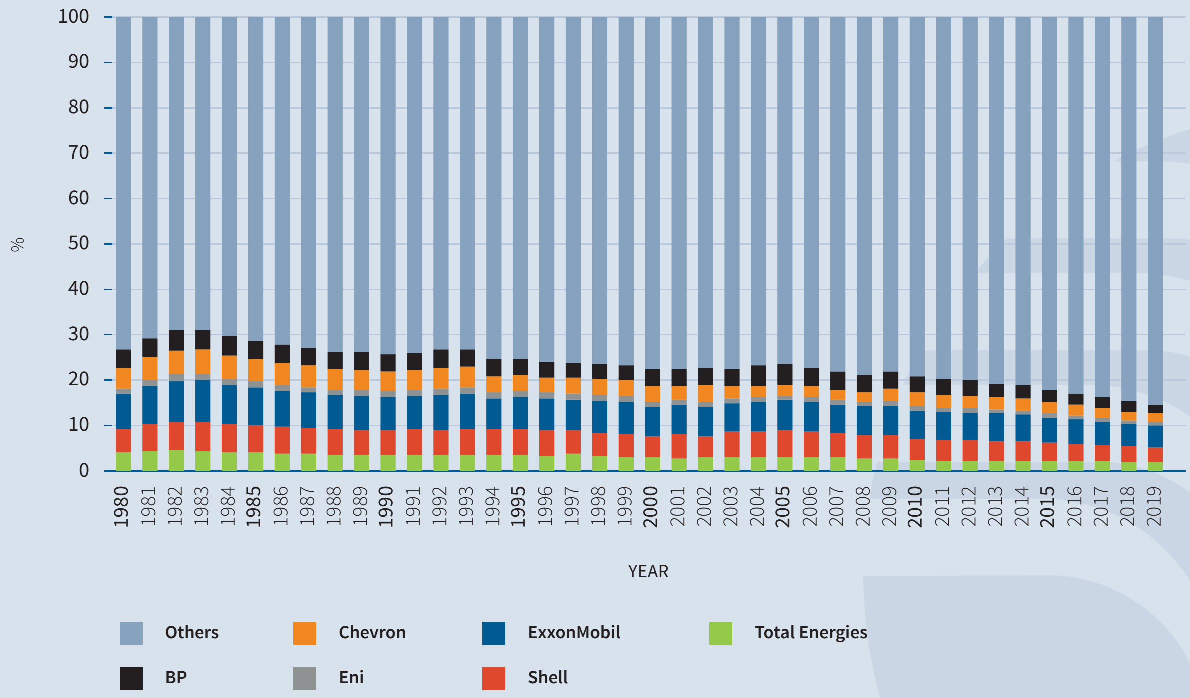
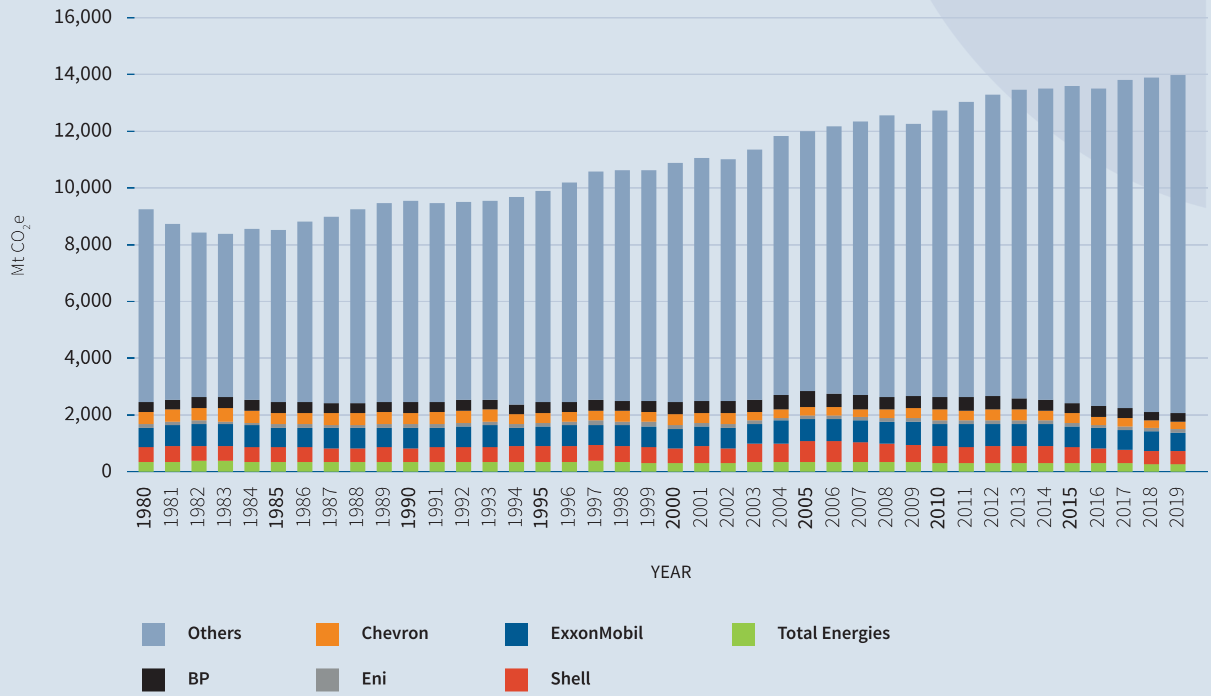


FIGURE 6: EMISSIONS FROM THE SUPERMAJORS' REFINING OIL SEGMENTS, 1980–2019

OIL SUPERMAJORS' REFINING SEGMENTS EMISSIONS (%) 1980–2019



OIL SUPERMAJORS' REFINING SEGMENTS EMISSIONS (Mt CO_2e) 1980–2019



As a point of comparison, Table 2 also presents extraction-based emissions for the six supermajors from the Carbon Majors 2018 dataset. The shares of the global sectors' emissions are only given for the oil refining and petroleum products sales segment as they are based on our model.

Moreover, while the carbon footprints of the supermajors' refining and sales segments vary, there is a coefficient of variation of 1.43% among the supermajors' carbon intensities in the refining segment and 1.06% among the supermajors' carbon intensities in the sales segment.[21] Both coefficients of variation are much lower than 1, which indicates a narrow difference between the carbon intensities of the supermajors in each segment.

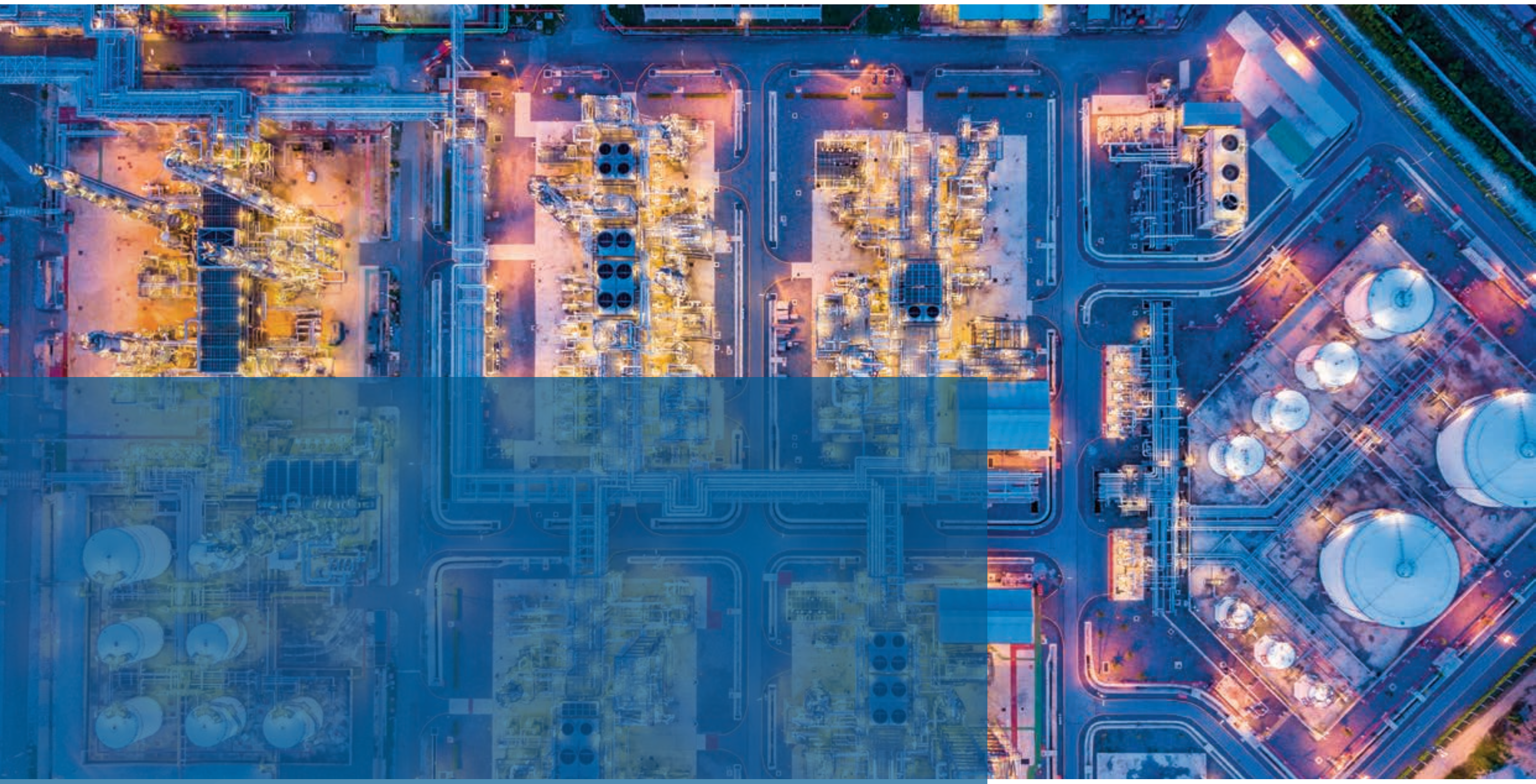
This result is not surprising as the supermajors refine and sell petroleum products originating from crude oil extracted by themselves but also by other companies. For instance, the oil used for more than 50% of Shell's sold products comes from third parties (Shell 2021c). When Shell sells these petroleum products, the carbon embedded in them comes from multiple oil fields associated with different API gravity values, refinery efficiencies, distribution distances which also means that the API gravity of Shell's typical oil fields as well as the impact of Shell's refinery efficiency and distribution network is diluted in a portfolio of API gravity, refinery efficiency and distribution distance values associated with oil coming from other companies.

TABLE 2: CUMULATIVE CARBON FOOTPRINTS AND MARKET SHARES OF THE SUPERMAJORS

ENTITY		MT CO_2e	% OF GLOBAL SECTOR (BASED ON OUR MODEL)
Oil Refining (1980-2019)	BP	15,827	3.57%
	Chevron	14,693	3.32%
	Eni	4,882	1.10%
	ExxonMobil	29,710	6.71%
	Shell	22,389	5.06%
	TotalEnergies	13,722	3.10%
Petroleum Products Sales (1980-2019)	BP	40,394	7.94%
	Chevron	28,659	5.64%
	Eni	4,450	0.88%
	ExxonMobil	46,187	9.08%
	Shell	44,444	8.74%
	TotalEnergies	13,976	2.75%

FOOTNOTES

21 For each sector, we calculate the carbon intensity by dividing the total emissions (in Mt CO_2e) by the total volume (in billion barrels) of either oil refined by all refineries or petroleum products sold, as the case may be, from 1980 to 2019. We then calculate the standard deviations of the carbon intensity of the six supermajors in each sector. Finally, we divide each standard deviation by the mean to calculate the coefficient of variation. Coefficients of variation lower than 1 indicate low variability. Coefficients of variation equal to or higher than 1 indicate high variability.



CONCLUSION

The design of our life-cycle model has addressed several limitations of the current literature:

1. To address the lack of a method to estimate emissions from the whole oil value chain, we build our estimation model on three commonly used models in the upstream, midstream, and downstream sectors and incorporate a range of stages within the oil value chain defined by government agencies, industry associations, and other stakeholders.
2. To reflect the differences in emission factors resulting from different geographies and technology changes, we estimate country-specific emission factors.
3. We validate the statistical significance of API gravity to emissions and apply the decision-tree model to calculate non-linear estimations of upstream emissions and the production rates of the refining sector, which we later use to estimate downstream emissions.

4. To create a time series of country-specific emission factors, we examine the changes in default emission factors and key parameters over time.

Applying our life-cycle model to refinery output and data on the sales of petroleum products, both by each supermajor and globally, we separately estimate their carbon footprints for both the refining and petroleum products sales sectors. These carbon footprints are not meant to be added up as they overlap.

The petroleum products sales sector sold a total of approximately 1,128 billion barrels of petroleum products from 1980 to 2019, leading to emissions of approximately 508 Gt CO_2e, nearly doubling its annual carbon footprint over the period. The supermajors jointly account for approximately 35% of the cumulative carbon footprint of the sector from 1980 to 2019, which reflects the market concentration in the sector.

The oil refining sector refined a total of approximately 984 billion barrels of crude oil from 1980 to 2019, leading to emissions of approximately 443 Gt CO_2e, with an increase of approximately 51% in its annual carbon footprint over the period. The supermajors jointly account for approximately 23% of the cumulative carbon footprint of the sector from 1980 to 2019, which reflects a lower but still significant market concentration in the refining sector.

The six supermajors own a sizable share of the oil refining and petroleum products sales sectors. Focusing only on their upstream activities ignores the depth of their hold on oil value chains. This paper sheds light on their contribution to emissions from the midstream and downstream levels of the value chain.

The report also scrutinizes companies' accounting methods to report emissions and concludes that company numbers rely on various and not fully transparent reporting boundaries, volume, and emission accounting methodologies. Most problematic is that most supermajors fail to report scope 3 emissions comprehensively, and in any event, there is a lack of time-series data of scope 3 emissions. In addition, the volume and emission accounting method might underestimate emissions in three ways: by omitting the emissions of third parties in the company's value chain (e.g. when a company sells petroleum products produced and refined by other companies or when it refines products later sold by other companies), playing with boundaries, or omitting data from non-operated JVs.

Our carbon footprint estimation also attempts to address some of the current limitations of company emissions reporting. Even so, we acknowledge that our methodological approach, described in detail in the full report, presents its own limitations. These limitations attest to the lack of data transparency and standardized carbon accounting at both country and corporate level, which prevents informed decision-making on those holding the levers of influence on companies: investors, consumers, and policymakers. Without consistent and transparent emissions accounting, companies' net-zero commitment and target settings are meaningless. To address these limitations, the Coalition on Material Emissions Transparency (COMET), supported by the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC), will create a harmonized greenhouse gas calculation framework applicable to all mineral and industrial supply chains.

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