Carbon Majors:
Updating activity data, adding entities, & calculating emissions:
A Training Manual

By Richard Heede
Climate Accountability Institute
30 September 2019
Climate Accountability Institute
Principal Investigator: Richard Heede
heede@climateaccountability.org
1626 Gateway Road
Snowmass, CO 81654 USA
970-343-0707 mobile

Copyright © 2019 Climate Accountability Institute

Report commissioned by:
Union of Concerned Scientists
Cambridge, MA
www.ucsusa.org
Project coordinator: Kathy Mulvey, kmulvey@ucsusa.org
Project supervisor: Peter Frumhoff, pfrumhoff@ucsusa.org

The author is grateful for the technical reviews provided Kathy Mulvey & Peter Frumhoff
Any errors and shortcomings are the author’s.

Note on units: International SI units are used throughout, except where reporting is in bbl of oil, cubic feet of natural gas, or (short) tons of coal. Emissions of methane are expressed in CH4 or in CO2-equivalent terms (CO2e; AR4: 100-y, 28xCO2).

Above: Sunset over Iraqi petroleum flares; Kuwait oil fires, 1990s; Melting globe.
TABLE OF CONTENTS

Foreword & Acknowledgements vi

1. Introduction 1

2. The process and methodology: an overview 3
   a. Adoption of the original methodology & exceptions
   b. Foundations of the Methodology
   c. Carbon Majors: the ecosystem
   d. Carbon Majors: principles
   e. Other protocols relevant to oil, gas, and coal emission inventories
   f. Units

3. Database architecture, data sources, and updating: an overview 7
   a. Database architecture
   b. Company types and source data
   c. Investor-owned companies (IOCs)
   d. State-owned entities (SOEs)
   e. Government-operated fossil fuel production (coal only)
   f. Mergers & acquisitions

   a. Acquiring Production Data: Investor-Owned Companies
      i. Investor-owned companies
      ii. Data entry and documentation in the Carbon Majors worksheets
      iii. Data entry: an example: Chevron (CVX)
      iv. Coal companies
      v. Data entry: an example: Peabody (BTU)
      vi. Data entry: other companies
      vii. State-owned entities
   b. Guidance for State-Owned Companies
      i. State-Owned Oil & Gas Companies
      ii. State-Owned Coal Producers
      iii. Nation-State / Government-Operated Coal Producers
   c. Cement producers
   d. Calculating scope 1 direct emissions and summing cumulative emissions
   e. Cumulative sums for each and every Carbon Major
   f. Inserting production data and supporting information in entity worksheets

5. Potential additions to the database 29
   a. Expanding the list of companies
   b. Creating new worksheets for data entry
   c. Mergers and acquisitions
   d. Worksheets, dynamic links
   e. Acquiring and updating global CO2 and CH4
   f. Summary worksheets for climate modelers

6. Communicating the results 33
   a. Charts and tables
   b. Innovative graphical ways to communicate
   c. Creating PDFs
   d. Posting results
   e. Open Access requests
   f. Media & outreach

Annexes

Annex A: Emission Factors and non-energy uses 39
Oil, natural gas, and coal: Emission Factors
Oil, natural gas, and coal: Non-energy uses
Annex B: Direct operational (scope 1) emission sources

Scope 1 emissions: crude oil & NGL
Scope 1 emissions: natural gas
Scope 1 emissions: coal
Scope 1 emissions summary
Cement production: Scope 1 process-related emissions

Annex C: Product-related (scope 3, category 11) emission sources

Annex D: References

Annex E: List of entities and worksheets

Annex F: Glossary & conversions

LIST OF FIGURES

Fig. 1. Global and Carbon Majors CO2 emissions 1810-2017 2
Fig. 2. Carbon Majors and unattributed emissions, % 2
Fig. 3: Flow chart of data entry to final results of Carbon Majors 7-8
Fig. 4: SEC’s EDGAR database of company filings, example of Chevron 11-12
Fig. 5: Chevron net production of liquids and natural gas, in Form 10-K for 2018 13
Fig. 6: Chevron data entry in OilGasAdnoc-EnCana.xls 14
Fig. 7: Chevron data entry in OilGasAdnoc-EnCana.xls: oil and gas detail for 2018 15
Fig. 8: Detail of oil production by Chevron, from SumOil.xls 15
Fig. 9: Detail of product-related oil emissions calculated for Chevron, from SumOil.xls 15
Fig. 10: Peabody coal production worksheet, from CoalPeabodyXstrata.xls 18
Fig. 11: Detail of Peabody coal production worksheet, from CoalPeabodyXstrata.xls 18
Fig. 12: Detail of product-related coal emissions calculated for Peabody, from SumCoal.xls 18
Fig. 13: Detail of product-related coal emissions calculated for Peabody, from SumCoal.xls 19
Fig. 14: Detail of product-related coal emissions calculated for Peabody, from SumCoal.xls 19
Fig. 15: Detail of Saudi Aramco oil production, 2015-2018, from “OilGasSaudi_Yukos.xls” 21
Fig. 16: Cemex net emissions, million tonnes CO2 24
Fig. 17: Detail of Chevron’s product and operational emissions, in “EntitiesAbuDhabi-Czech.xls” 25
Fig. 18: Detail of Chevron’s emissions by gas, in “SumEach&Every1850-2018 Sum Aug19.xls” 25
Fig. 19: Worksheet summing cumulative emissions for every Carbon Major, in “SumRanking.xls” 26
Fig. 20: Detail of cumulative emissions for Chevron, in “SumRanking.xls” 26
Fig. 21: Peabody Energy data entry worksheet, pages 1 & 2, with production data screenshots 27-28
Fig. 22: Global and Carbon Majors CO2 emissions 1810-2017 33
Fig. 23: Carbon Majors and unattributed emissions, % 33
Fig. 24: Top Ten carbon major companies operational and product emissions 1965-2017 34
Fig. 25: Top Twenty carbon majors cumulative scope 1 and scope 3 emissions 34
Fig. 26: Top Twenty carbon majors cumulative scope 1 and scope 3 emissions 34
Fig. 27: Logo “buttons” of leading company emissions scaled to cumulative emissions 34
Fig. 28: Detail of Oil Production for all 72 oil producers 1937-2018 36
Fig. 29: Detail of “Each&Every1850-2018 Sum.xls” data for 15 of 103 companies 1926-2018 36
Fig. 30: “Page Setup” Row & column headings and Comments “At end of sheet” selected 37
Fig. 31: Peabody cell note documenting data source for 2018 coal production (see detail Fig. 11) 37
Fig. 32: Carbon Majors chart by Science magazine 37
Fig. 33: Carbon Majors chart by The Guardian 38
Fig. 34: Petroleum products non-energy uses and net carbon storage worksheet 40
Fig. 35: Calculation of final emission factor for petroleum (“Oil Emissions Factor Calc” SumOil.xls) 40
Fig. 36: Scope 1 operational emissions applied to Chevron, in “Entities AbuDhabi-Czech.xls” 42
Fig. 37: Scope 1 flaring & venting rates in “AncillaryCH4&CO2.xls” linked to all Scope calcs 43
Fig. 38: Chevron emissions from oil & gas sales (red) vs production (blue) 46
## List of Tables

Table 1: Investor-owned oil and gas companies  
Table 2: Investor-owned coal companies  
Table 3: State-owned oil and gas companies  
Table 4: State-owned coal companies  
Table 5: Government-operated: oil, gas, coal, cement  
Table 6: Cement companies  
Table 7: Oil & gas and coal companies added in 2019  
Table 8: Potential new company additions to database  
Table 9: Top Twenty carbon major companies operational & product emissions cumulative to 2016  

Annex Tables:

Table A1: Emissions factors for combustion of crude oil & NGLs, natural gas, and coal  
Table A2: Petroleum products non-energy uses and net carbon storage worksheet  
Table B1: Emission factors for vented, flared, and fugitive carbon dioxide and methane  
Table C1: Top Twenty carbon majors’ operational and product emissions cumulative to 2016  
Table F1: Conversion factors
Foreword & Acknowledgements

I wish to thank my colleagues at Union of Concerned Scientists who encouraged me to write this *Training Manual* — and indeed to launch the search for a long-term and durable institutional host to take on the responsibility of updating the Carbon Majors database that I started working on fifteen years ago. In particular I want to thank Peter Frumhoff, who has been the champion not only of the database but of its scientific value to climate modelers, analysts, climate leaders and policy experts, as well as to litigators in pursuit of climate justice and the protection of human rights. I want to thank my UCS colleagues Kathy Mulvey and Brenda Ekwurzel — with whom I have enjoyed close collaboration on several projects of mutual interest including their attentive edits of this *Manual*. I owe them my gratitude and respect for the accomplishments we have made together.

It is also due to UCS funding that much of this work has succeeded, and I thank Cheryl Schaffer, Kathleen Rest, and Nancy Cole whose support and endless encouragement has buoyed my spirit and commitment over many years.

This *Manual* and the database and its methodology rests firmly on my early collaboration with colleagues at Greenpeace International (Kristin Casper, Jasper Teulings, & Nina Shultz) and Climate Justice Programme (Keely Boom, Steve Leonard, and Peter Roderick).

I also want to acknowledge the crucial nature of philanthropic funding from Wallace Global Fund and Rockefeller Brothers Fund. Without which I’d be sipping rum at some beachfront on Bora Bora.

And of course I cannot survive long without the encouragement and love of my partner Karina, who has to put up with lots of late nights and long days. Bring the rum!
Introduction

It is important for a wide range of stakeholders and the public that companies report emissions of greenhouse gases attributable to their facilities, operations, and marketed products. Most leading companies in every industrial and commercial sector, including fossil fuel producers, make a good-faith effort to report on material emissions in their corporate sustainability reports.

The reporting standards promulgated by various standards organizations — such as World Resources Institute’s (WRI) *Greenhouse Gas Protocol* or American Petroleum Institute’s (API) *Compendium* (see Annex D: References: Protocols) — focus on voluntary reporting of direct (Scope 1) and indirect (Scope 2) operational emissions (see Chapter 2: Protocols relevant to oil, gas, and coal emission inventories). These and other inventory protocols do not require that the far larger emissions from the carbon fuels marketed to global consumers when used as intended be included in the corporate inventory.$^1$ These end-user combustion emissions release ~nine times more carbon dioxide than the operational emissions to produce and deliver those carbon fuels. Fossil fuel companies, have not historically been held accountable for emissions from products sold to their global customers. An ethical philosopher (Shue, 2017) argues that fossil producers bear substantial moral, financial, and possibly legal responsibility for the foreseeable and foreseen climate impacts of their products, and thus an obligation to contribute to mitigation and adaption costs. Several cities and counties, a trade association, and the attorneys general of two U.S. states are exploring these questions through the U.S. and international legal institutions (Hasemyer, 2019; Jarvis 2019).

**Fig. 1.** Global emissions of carbon dioxide for fossil fuel use and cement production from 1810 to 2017 (black) and the emissions attributed to 103 major carbon producers (red). **Fig.2.** Carbon Majors and all unattributed fossil fuel use and cement emissions cumulatively from 1751 to 2017.

Given the paucity of company reporting on the full range of attributable emissions it was the Climate Accountability Institute’s initiative, begun in 2003, to develop and apply a robust, fair, and peer-reviewed methodology to quantify the emissions that result from the carbon fuels produced and marketed worldwide by major fossil fuel producers (Fig. 1). Unlike the protocol belatedly being used by some oil and gas producers that quantifies emissions from products *sold*,

---

$^1$ These Scope 3 emission sources fall under voluntary reporting, and include 14 categories of across the company supply chain from raw material inputs, end-of-life disposal, employee commuting, commercial air travel, and emissions from sold products.
our methodology focuses on quantifying emissions from net equity carbon \textit{production}. Both methodologies have their uses, the former emphasizing downstream impacts, the latter upstream; we focus on the companies that \textit{extract} the carbon fuels so as to avoid the complexities of oil bartering, refiners using oil purchased from other parties, fuel re-sellers, transporters, and so on. This manual describes the methods that were developed to address the growing demand by different stakeholders for data on emissions traced to the industrial carbon producers.

It is fundamentally important to provide the accounting required to hold oil, gas, and coal companies morally, financially, and legally responsible for exacerbating foreseeable climate damages. To do so we first need to identify which extant companies produced the world’s historical supply of carbon fuels, and, secondly, to quantify how much of the carbon in those fuels has been oxidized to the atmosphere as carbon dioxide. This is precisely what the Carbon Majors database has accomplished: traced emissions to the atmosphere from the fuels extracted by fuel and by year, historically from as early as 1854 to the present.

Global fossil fuel and cement emissions since 1751 total 1,574 GtCO$_2$, of which the 103 Carbon Major entities account for 69.8\% over the full global history from 1751 to 2017. Disaggregating for each fuel, Carbon Majors account for 79\% of global emissions from crude oil & NGL, 71\% of natural gas, 62\% of coal, 60\% of cement, and 51\% of flaring.

Historical emissions are important because past emissions are the main driver of climate change. Historical source attribution is important for diverse stakeholders. Some stakeholders seek historical evidence of when companies demonstrably became aware of the threat of climate change to the public welfare as well as to their business objectives. Our database does not set the clock starting on corporate accountability, but the data is open source and available to all potential users seeking a specific dataset. The results comprise the basic inputs to analyses, modeling, financial research, and litigation of the climate impacts of emissions traced to major carbon producers (Ekwurzel et al., 2017; Licker et al., in review; Jarvis 2019).

The Carbon Majors database is also important going forward because historical emissions are useful in considering each company’s remaining carbon budget under the Paris Agreement.

For all of these reasons, the database would ideally be maintained in versions that note any changes from the original methodology so transparent comparisons can be made among different applications. This is expected as the methods rely on international protocols such as those associated with the Intergovernmental Panel on Climate Change (IPCC). For example, IPCC protocols for calculating carbon dioxide equivalents for methane and other similar climate drivers in country greenhouse gas inventories have shifted over time.
<2>

The process and methodology: an overview

This *Training Manual* focuses on the how-to of updating activity data (i.e., production of oil, other liquids, natural gas, coal, and cement) for the several categories of Carbon Major entities: investor-owned companies (IOCs), state-owned entities (SOEs), and Nation-States for which adequate corporate ownership data is unavailable (NS; only for coal, plus one cement producer: China). Each type of entity requires a different approach and differing sources of production data. The priority is the use of company-reported activity data published in official sources.

All IOCs and many SOEs file reports containing production data with the U.S. Securities and Exchange Commission or do so in *Annual Reports*. Many state-owned companies are partially-owned by individual and institutional shareholders. These include Equinor, Petrobras, and Gazprom, and are considered state-owned if more than fifty percent of shares are controlled by the state. Equinor (formerly Statoil) is 67% owned by the Norwegian government, Petrobras is 64% owned by the government of Brazil, and Gazprom is 50.003% owned by the Russian Federation. In the coal sector, Coal India is 78% owned by the government. Many oil and gas companies in the Middle East, Latin America, and Africa are wholly-owned by their respective states, and thus report production directly to their sole shareholder, and in many cases only report summary data to the public.

In each of these cases the *Training Manual* goes through the steps required to update the database with the most recent data available in order to assure the integrity and usefulness of the database for a range of applications and audiences.

**Adoption of the original methodology & keeping track of versions**

Since the primary aim of the Carbon Majors database updates is the consistent application of the original methodology (Heede 2013, 2014, 2019) there are only a few expected changes to the updated database release versions. These include:

- updating the Global Warming Potential (GWP) of methane — periodically revised in the IPCC’s *Assessment Reports*
- noting the incorporation of the emissions calculations for companies that are no longer extant but have become part of another company as through mergers and acquisitions (example: Royal Dutch Shell acquired BG in 2016) while maintaining the historical emissions of entities no longer extant (e.g. Former Soviet Union emissions will always be an archive of data in the database)
- adding a new fossil fuel or cement company when the criteria have been met (i.e. emissions threshold is met and historical production data is available)
- revising production data with new information from companies or other sources; including filling interpolated gaps in the dataset, revised production data, extending the dataset to earlier years (e.g., RWE prior to 1965 to its founding in 1898; Phillips gas production prior to 1937; Wintershall prior to 1998), new data on rank of coal mined, revised net production data, granular data on liquids production by type (crude, condensate, natural gas liquids, bitumen, oil sands, synthetic oil), etc.
Foundations of the Methodology
The methodology is discussed in detail in the Methods and Results Report (2013, 2019) for each of the source categories: crude oil and natural gas liquids, natural gas, coal, and cement. We base the methodology on the World Resources Institute’s (WRI) 2004 Greenhouse Gas Protocol, elements of American Petroleum Institute’s (API) Compendium (2009), and on the methodology in Marland & Rotty (1984). The Marland and Rotty methodology underpins the historical global emissions database developed at U.S. Dept of Energy’s (DOE) Carbon Dioxide Information Analysis Center (CDIAC), and now maintained by the Global Carbon Project in Japan (Marland et al. 2011; Global Carbon Project 2018; Le Quéré et al. 2018). The percent of global cumulative historical emissions from 1751 to the latest activity year in the database is calculated for every entity in the Carbon Majors database.

Carbon Majors: the ecosystem
The database uses Excel as a platform, and from activity data of annual production through to summary results and charts and figures every worksheet is dynamically linked to assure that revisions and updates and new additions all flow through to the summary worksheets.

Links between worksheets do get broken occasionally, particularly between workbooks, and happen for a number of reasons. Restoring lost links is straightforward.

Note: The Climate Accountability Institute works on Excel 2011. While we have updated our software to Office 365/2018, Microsoft has — though contrary to its own specs— disabled the function of enabling the printing of cell notes, which is our preferred location for documenting all data sources, reporting notes, fuels by type, reporting units, etc. This has enabled documentation to be co-located with the production data or other specific information, such as emission factors, mergers and acquisitions (M&A), etc. This functionality is supported in MS Excel for Windows, but not OS for Macs. Repeated attempts to inform Microsoft of this problem and seek a patch have been unsuccessful.

Note: users of the Carbon Majors database results may import the data into another platform on the proviso that the model and results are open access, and the model and the results are both documented and transparent.

Carbon Majors: principles
Foundational principles include
1. open access to all potential users of the database,
2. full transparency of methodology and results,
3. no paywalls for access to PDFs to all worksheets (except transactional costs for special requests and particular datasets or subsets)

In addition, in order to maintain reliability, we urge:
• vigilant commissioning of data entries, links, and calculations to identify and correct erroneous results,
• error detection protocols,
• full documentation of data sources,
• notation of ambiguities in reporting (did the company change reporting units?),
• sleuthing to trace and correct discontinuities in production data (which might be due to an acquisition or sale of assets or a change in reporting such as inclusion of re-injected gas production) or emission estimates (which might result from an erroneous change in an emission factor or coal rank).
Protocols relevant to oil, gas, and coal emission inventories

The API Compendium and the WRI Protocol focus on operational emissions, termed Scope 1 and Scope 2 in the Protocol, and are followed by most fossil fuel companies (as well as companies in other economic sectors) in exploration and production (SIC 1300s), petroleum refining (SIC 2900s), and chemicals and plastics (SIC 2800s).

Scope 1 direct operational emissions from owned, controlled, or leased assets (such as combustion emissions or flaring at refineries, CO₂ vented at gas processing facilities, methane leakage at natural gas production sites or vented at coal mines) are included in the Carbon Majors methodology.

Scope 2 emissions from electricity or steam purchased by the entity from third parties (such as electric utilities) are excluded. The reason for this exclusion is to avoid double-counting emissions already that are already accounted for by the primary extractors of the carbon fuels. Our focus is on the carbon in extracted fossil fuels and emissions traced to the disposition of refined carbon fuels, and not on who buys and combusts the fuels, such as automobile drivers, airlines, or electric and gas distribution utilities.

Scope 3 emissions are included, although limited to WRI’s Scope 3 / category 11: use of sold products, but modified to quantify emissions from each fossil fuel company’s net production of oil, gas, or coal. We thus exclude emissions from crude oil purchased from other oil companies for use in company-owned refineries or marketed through its own distribution channels, or natural gas purchased for re-sale, or coal sold on behalf of other producers. In short, our focus is on tracing the carbon from the lithosphere to the atmosphere by way of each company’s net equity production of primary carbon fuels. This is the advance provided by our original published work and dataset (Heede 2013, 2014), namely tracing two-thirds of global fossil fuel emissions from 1751 to 2010 to the ninety major carbon producers (updated to 2017 activity data by 103 entities in the most recent update). This allows for shifting the focus to the corporate entities with their collective hands on the throttle of carbon development, new reserves, and future emissions, and whether these same entities shift investments from new fossil fuel reserves to low- or zero-carbon sources in order to help meet the infrastructure demands of the 1.5°C pathway of the Paris Agreement.

Units

Companies report production in myriad ways, though most often in common U.S. units such as cubic feet of natural gas (cf), 42-gallon barrels of oil and natural gas liquids (bbl), or short tons or metric tonnes of coal. Most oil and gas companies report daily production, such “1,723 thousand bbl per day (kbpd),” (Chevron daily production of crude oil, condensate, NGL, and synthetic oil in 2017, including production by consolidated companies and affiliates), which is then converted to annual production by multiplying by 0.365 to get 629 million bbl (Mb). Every oil and gas worksheet is set up to automatically perform this calculation. Likewise, natural gas
production is typically reported in million standard cubic feet per day, thus, say, 6,032 thousand cf per day, equals 2,202 Bcf (Chevron data for 2017).

We consistently report company annual production in million bbl (Mb), billion cubic feet of gas (Bcf), and million metric tonnes of coal (Mt). We always convert production reported in million short tons (Msht) to million metric tonnes (Mt). The project calculates emissions in metric tonnes (million tonnes CO₂, MtCO₂), uses emission factors in metric, and compares company emissions to global emissions annually (using CDIAC/GCP data; Le Quéré et al. 2018; Global Carbon Project 2018). Foreign companies (especially Russian) report in metric units such as billion cubic meters of gas (Bcm) and tonnes of crude oil are, for consistency, converted to Bcf and Mb, respectively. The oil and gas industry was first established in the United States, and these units have survived into the modern age, for better or worse.

CAI accounts for the isotopic values of carbon and oxygen in converting between C and CO₂: 3.664191. Typical convention is the simplified atomic weights of C12 and O16, thus 3.667. It would be easier to calculate emissions on the basis of energy content of produced carbon fuels, such as GJ/bbl or GJ/tonne of bituminous coal; however, companies report in physical units, not energy content.

We note the conversion factor for natural gas in barrels of oil equivalent (boe) — which range from ~5,500-6,100 cf/bbl — although we consistently seek data in physical units (Bcf or Bcm). Note: we consistently use “M” to mean million, or mega, not the U.S. convention of “m” or “M” to designate thousand, based on the roman “mille.” The U.S. convention of “mm” to mean thousand thousand, or million, is never used.

Note: Scope 3 production-related emissions do not include Scope 1 emissions from flaring, CO₂ venting, fugitive and vented methane, and own fuel use — all of which are calculated in subsequent worksheets.

\(^2\) Standard atomic weight of isotopic carbon is 12.0107, oxygen 15.9994, thus \((12.0107 + 2\times15.9994)/12.0107 = 3.664191\). Originally based on the WRI work of Kevin Baumert, this conversion factor is also used by CDIAC and Global Carbon Project.
Database architecture, data sources, and updating: an overview

Database architecture
The database is composed of ~220 Excel worksheets, integrated and dynamically linked in three tiers, from the “top” (worksheets for entering production data for each fuel for each company over its extractive history) to the “middle” worksheets in which Scope 3 emissions are calculated using emission factors and adjustments for non-energy uses to the “bottom” worksheets that quantify ancillary Scope 1 emissions and sum all Carbon Majors. This last tier of worksheets also compares each company’s cumulative historical emissions to global emissions of carbon dioxide from fossil fuel and cement sources from 1751 to 2017.

The current list of Carbon Majors now numbers 103 entities (after accounting for mergers & acquisitions and new companies meeting the threshold were added in 2019; see Annex E for complete list). Attributed emissions totals 1.22 trillion tonnes CO₂ equivalent (TtCO₂e) through 2017, or 69.8 percent of global fossil fuel & cement emissions (1.75 TtCO₂e) from 1751 to 2017.

Fig. 3. Flow chart of data entry to final results of Carbon Majors

Legend:
- **Main worksheets**
- **Ancillary worksheets**
- Production data inputs on entity worksheets: oil (Mb), natural gas, (Bcf), coal (Mt). 103 worksheets
- Emission factors for each fuel, in tCO₂ per Mb, Bcf, and Mt. 3 worksheets
- Non-energy uses for each fuel. 3 worksheets
- Final emission factors for each fuel, in tCO₂ per Mb, Bcf, or Mt
- Scope 3 production-related emissions for all fossil fuel major carbon producers, by year. Oil, Gas, and Coal
Company types and source data

The methodology relies on company-reported data for production of oil, gas, and coal. We prioritize the use of company reporting filed with the U.S. Securities and Exchange Commission, which is available for all investor-owned companies headquartered in the United States or that have operations, sell fuels, or own production, transportation, or refinery assets in the U.S. It is acceptable to use data reported in company annual reports.

Investor-owned companies that have no reportable operations in the United States issue annual reports to their shareholders, and frequently summarize production on their websites or in Data Books and the like.
Investor-owned companies (IOCs)
Companies headquartered in the U.S. file Form 10-K; Canadian companies file Form 40-F, and other international companies that have operations or assets in the United States file Form 20-F. The EDGAR website enables filtering for, say, 10-Ks, resulting in a list of each of its 10-K filings going back to about 1993/1994. Earlier Annual Reports or SEC filings can be found in university libraries, online or microfiche or paper (e.g., Columbia University, Georgia State, Rice University, UC-Berkeley). ProQuest (proquest.com) has an uneven collection prior to year 1990, but may serve as a useful resource for historical Annual Reports if needed; a free one-month trial is available on request.

State-owned entities (SOEs)
State-owned companies typically report reliable data on net equity production of oil and gas, especially companies with partial state ownership, such as Equinor, Petrobras, and Gazprom, all of which are majority-state-owned (>50%).
However, wholly state-owned companies — particularly sovereigns such as Petroleos de Venezuela, Bahrain Petroleum, or National Iranian Petroleum — do not provide up-to-date or reliable data on their annual production, nor clearly define whether production is net equity, operated, or territorial production. We corroborate self-reported data (if available) with third-party reports such as Oil & Gas Journal (OGJ100). CAI does not use data from sources with high paywalls (such as proprietary databases by Rystad Energy, Global Data, IHS, Bloomberg, or Wood MacKenzie), so that any analyst can check the data we have used in our databases at any university library or using sources freely available on the web.
While roughly 40% of oil & gas companies are state-owned (29 of 72), only two coal companies (Coal India and Singareni Collieries) in our database are state-owned.

Government-operated fossil fuel production (coal only)
As these economies privatize state-owned production assets (as Poland and China are doing), we recommend that the state-operated production data be replaced with current and historical data on company production. In Russia, for example, this includes SUEK, KuzbassRazrezUgol, and Severstal, and, in China, Shaanxi Coal, Shenhua Group, Datong Coal, and ChinaCoal (see ch. 5, table 8). Historical records are often sparse, ownership (central- or regional government-owned) is often ambiguous, and publications are often not available in English. Nonetheless, a new host organization may have opportunities to expand the historical production data for new companies.

Mergers & acquisitions
The updating process requires accounting for mergers and acquisitions that have occurred since the last update. Mergers & acquisitions of entire companies do have be tracked: this is discussed
in Annual Reports and press releases; the *Oil & Gas Journal* also covers major M&As in the OGJ100 and OGJ150 issue (typically in September each year). For example, in 2016 Royal Dutch Shell acquired BG (British Gas) and HeidelbergCement acquired the controlling interest in Italcementi. Chevron announced the acquisition of Anadarko in a stock and cash offer in April 2019. However, we account for the acquisition in the month the deal is consummated, which typically takes a year or longer. See chapter 5 and Annex E for a listing and discussion of new additions.

Organic acquisition of operating assets, such as individual wells or fields, are reflected in operating statistics by the seller and the buyer and need not be accounted for separately.

The historical production data and the calculated emissions should be attributed to the extant company. In the case of Royal Dutch Shell’s acquisition of BG, we added BG historical production of oil and gas from 1988 to 2015 to Shell’s oil and gas (and coal) data from 1892 to the present. Shell’s Form 20-F for 2017 accounts for its acquisition of BG’s assets, and totals 666 million bbl of liquids (Mb) and 3,894 billion cubic feet of natural gas (Bcf).
Step-by-step instructions: updating Carbon Major Entities

Here is the heart of the Training Manual: the operational, step-by-step instructions of where to find the required data and how to apply it to estimate emissions. We also discuss documenting source data, using cell notes, printing, linking worksheets, verifying the results, and so forth.

The priority is on acquiring production data from company records and declarations, such as filings with the U.S. Securities and Exchange Commission (EDGAR database, Chapter 3). An acceptable alternative is data published in company annual reports, or posted on their website or in Fact Books issued by the company. Secondary sources such as Bloomberg, or Global Data, or proprietary databases such as WoodMackenzie or Rystad, or compilations in Oil & Gas Journal are acceptable, if original company-reported data is not available.

ACQUIRING PRODUCTION DATA: INVESTOR-OWNED COMPANIES

Investor-owned companies

Updating investor-owned net equity production is accessible for all companies filing with the SEC at:

www.sec.gov/edgar/searchedgar/companysearch.html

by viewing the html or PDF version of each company’s latest Form 10-K, 20-F, or 40-F. Investor-owned companies (IOCs) not reporting to the SEC — companies without assets or reportable operations in the United States — such as Rosneft (Russia), Repsol (Spain), and OMV (Austria) are discussed below, as are coal producers Anglo American (UK), Glencore (Switzerland), RWE (Germany), and Sasol (South Africa) that also do not file with the SEC.

Most IOC oil & gas companies do file with the SEC. The search and data entry process is as follows, using Chevron (ticker: CVX) as an example:

Fig. 4. SEC’s EDGAR database of company filings: search for Chevron (CVX) Form 10-K for 2018
We use Chevron’s 10-K for 2018, filed on 22 February 2019, as an example. We focus on equity production, which in Chevron’s case is in Section 1: “Business / Upstream” (last panel of Fig. 4). Clicking through to company reserves (CVX p. 4) is followed by a table of “Net Production of Liquids & Natural Gas” (Fig. 5). Reported production is often further detailed — such as net production and/or operated production, by consolidated and affiliated companies, net share of production-sharing agreements, production by geographic region — in a section “Management's Discussion and Analysis of Financial Condition and Results of Operations” or in Annexes to the filing. If historical reports are needed prior to online SEC submissions (earlier than ~1993), then company annual reports are a reliable source; oftentimes there is a table of key performance data or statistical annex at the end of the annual report. See Annex F for glossary.

**Fig. 5.** Chevron net production of liquids and natural gas, in Form 10-K for 2017 and 2018.

Data entry and documentation in the Carbon Majors worksheets
It is important to document the source of the data as well as other pertinent information in the annual entry. What qualifies as pertinent varies, but a short list includes liquids production by type, such as natural gas liquids (NGLs) and condensate, synthetic oil or heavy oil production (to inform consideration of adjusting the emission factor for a company’s production that would

---

3 The methodology assumes a blend of crude oil and NGL as 9:1, accounting for the differing emission factors. See *MRR.*
account for the higher carbon intensity of bitumen and synthetic oil, which is relevant for producers active in Athabascan oil sands, or a high proportion of NGLs and condensates, such as for Gazprom). Also note changes in reporting, such as net vs gross production (this is more pertinent in decades past; most operators now report net equity production), and whether natural gas is reported as “available for sale” or only as gross production. We want to identify net equity production (see glossary), not operated production. Note information that materially affects the emission of CO2 or methane to the atmosphere, such as quantities of raw gas production that is re-injected for reservoir pressurization. Mergers and acquisitions also have to be noted, and if a wholesale acquisition the extant company also acquires the historical emissions attributed to the acquired company. See “Mergers and acquisitions,” chapter 5.

Documenting data sources in cell notes is important not only for credibility but chiefly so that researchers, fact checkers, the database manager, or the companies themselves can verify that the data is entered correctly, and in the proper units. Correction and verification are core values. On occasion there are ambiguities in company reporting. Any uncertainties or ambiguities must be documented in the cell notes for future inventorists to review.

**Data entry: an example: Chevron (CVX)**

Chevron’s equity production of crude oil and NGLs (thousand barrels per day, or kbpd [“MBPD” in CVX, p. 5]) and natural gas (million cubic feet per day, Mcfpd [“MMCFPD”]). Chevron’s 2017 liquids production is reported as 1,723 kbpd, which, when entered in column “D” in the worksheet, is automatically multiplied by 0.365 to calculate annual liquids production of 629 million bbl (Mb) in column “T” (see Fig. 7). The data source is documented in the corresponding cell note — Chevron 2018 Form 10-K, page 5 — and relevant details, such as the production of natural gas liquids and condensate, or synthetic oil production, specified in a footnote to the table and noted in the cell note (Fig. 7).

**Fig. 6.** Chevron production data entry in OilGasAdnoc_Encana.xls (see Fig. 7 for detail)
Screenshots of Chevron oil (top) and gas (bottom) production data entry detail for 2012-2018, with cell note. Column “D” is crude oil and liquids production in thousand bbl per day; column “Y” is natural gas production in million cf/day.

Emission factors for each fuel type are built into each respective worksheet (see Annex B). Chevron’s production of crude oil and NGL (and synthetic and heavy oil) totaled 629 Mb in 2017 in “Oil Production” worksheet (Fig. 8).

In the “Oil emissions” worksheet each company’s annual production is multiplied by the emission factor of 0.3714 MtCO₂/Mb (appearing in the upper right of Fig. 9, and is linked to the Emission Factor worksheet. This calculates production-related emissions of CO₂ for each company for every year. For Chevron (Fig. 9) it estimates emissions of 234 MtCO₂ in 2017 and, summing Chevron’s production history from 1912 to 2018, estimates cumulative emissions of 38,484 MtCO₂. Annex A discusses the sources and derivation of emission factors and net non-energy use factors for each fuel.

The same format is used to quantify emissions traced to natural gas and coal producers, deducting for non-energy uses, and accounting for the highly variable carbon content of differing ranks of coal mined (lignite to anthracite); see Methods & Results Report (Heede 2013, 2014) for discussion and Table 1 in Annex A.
The production and emissions worksheets for crude oil, natural gas, and coal also link to estimates of global fossil fuel and cement emissions from international sources, chiefly, in recent years, from the Global Carbon Project (Marland et al. 2011; Le Quéré et al. 2018; Global Carbon Project 2018) that document global emissions of carbon dioxide from 1751 (for coal emissions), from 1870 (oil), from 1885 (gas), from 1928 (cement), and from 1950 (flaring).

The companies listed below file reports with the SEC, with the exception of Lukoil, OMV, and Polish Oil & Gas. These latter companies report net equity production to shareholders in Annual Reports and/or Factbooks, available online.

Table 1. Investor-owned oil and gas companies

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Data coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anadarko</td>
<td>USA</td>
<td>1945-2018</td>
</tr>
<tr>
<td>Antero (added 2019)</td>
<td>USA</td>
<td>2012-2018</td>
</tr>
<tr>
<td>Apache</td>
<td>USA</td>
<td>1985-2018</td>
</tr>
<tr>
<td>BHP Billiton</td>
<td>Australia</td>
<td>1970-2018</td>
</tr>
<tr>
<td>BP</td>
<td>UK</td>
<td>1913-2018</td>
</tr>
<tr>
<td>Canadian Natural Resources</td>
<td>Canada</td>
<td>1988-2018</td>
</tr>
<tr>
<td>Chesapeake (added 2019)</td>
<td>USA</td>
<td>1994-2018</td>
</tr>
<tr>
<td>Chevron</td>
<td>USA</td>
<td>1912-2018</td>
</tr>
<tr>
<td>ConocoPhillips</td>
<td>USA</td>
<td>1924-2018</td>
</tr>
<tr>
<td>Devon Energy</td>
<td>USA</td>
<td>1988-2018</td>
</tr>
<tr>
<td>Encana</td>
<td>Canada</td>
<td>1987-2018</td>
</tr>
<tr>
<td>Eni SpA</td>
<td>Italy</td>
<td>1950-2018</td>
</tr>
<tr>
<td>EOG (added 2019)</td>
<td>USA</td>
<td>1991-2018</td>
</tr>
<tr>
<td>EQT (added 2019)</td>
<td>USA</td>
<td>1992-2018</td>
</tr>
<tr>
<td>ExxonMobil</td>
<td>USA</td>
<td>1882-2018</td>
</tr>
<tr>
<td>Hess</td>
<td>USA</td>
<td>1958-2018</td>
</tr>
<tr>
<td>Husky Energy</td>
<td>Canada</td>
<td>1988-2018</td>
</tr>
<tr>
<td>Inpex (added 2019)</td>
<td>Japan</td>
<td>2004-2018</td>
</tr>
<tr>
<td>Lukoil</td>
<td>Russian Federation</td>
<td>1996-2018</td>
</tr>
<tr>
<td>Marathon</td>
<td>USA</td>
<td>1938-2018</td>
</tr>
<tr>
<td>Murphy Oil</td>
<td>USA</td>
<td>1983-2018</td>
</tr>
<tr>
<td>Noble (added 2019)</td>
<td>USA</td>
<td>1992-2018</td>
</tr>
<tr>
<td>Novatek (added 2019)</td>
<td>Russian Federation</td>
<td>2002-2018</td>
</tr>
<tr>
<td>Obsidian (added 2019)</td>
<td>Canada</td>
<td>1996-2018</td>
</tr>
<tr>
<td>Occidental</td>
<td>USA</td>
<td>1958-2018</td>
</tr>
<tr>
<td>OMV Group</td>
<td>Austria</td>
<td>1997-2018</td>
</tr>
<tr>
<td>Petoro (added 2019)</td>
<td>Norway</td>
<td>1999-2018</td>
</tr>
<tr>
<td>Pioneer (added 2019)</td>
<td>USA</td>
<td>1995-2018</td>
</tr>
<tr>
<td>Polish Oil &amp; Gas</td>
<td>Poland</td>
<td>1998-2018</td>
</tr>
<tr>
<td>Repsol (acq Talisman May 2015)</td>
<td>Spain</td>
<td>1964-2018</td>
</tr>
<tr>
<td>Royal Dutch Shell (acq BG Feb 2015)</td>
<td>Netherlands</td>
<td>1892-2018</td>
</tr>
<tr>
<td>Santos (added 2019)</td>
<td>Australia</td>
<td>1991-2018</td>
</tr>
<tr>
<td>Southwestern (added 2019)</td>
<td>USA</td>
<td>1988-2018</td>
</tr>
<tr>
<td>Suncor</td>
<td>Canada</td>
<td>1987-2018</td>
</tr>
<tr>
<td>Total SA</td>
<td>France</td>
<td>1934-2018</td>
</tr>
<tr>
<td>Wintershall (added 2019)</td>
<td>Germany</td>
<td>1998-2018</td>
</tr>
<tr>
<td>Woodside (added 2019)</td>
<td>Australia</td>
<td>1971-2018</td>
</tr>
</tbody>
</table>

Coal companies

All of the companies below are investor-owned (except for privately held Kiewit Mining) and publish annual reports, and most file 10-K or 20-F with the SEC, including Australia-based BHP, which owns coal and oil assets in the United States. Alpha Natural Resources acquired Massey Energy in 2011. Many leading oil and gas majors owned coal assets in the 1970s to 1990s; Chevron was the last to divest its coal assets in 2012. Unless divested oil company coal assets are
attributed to another extant coal company, the coal production is attributed to the divesting company, such as BP, Shell, Chevron, and ExxonMobil.

Table 2. Investor-owned: coal

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Data coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Anglo American</td>
<td>UK</td>
<td>1909-2018</td>
</tr>
<tr>
<td>2. Arch Coal</td>
<td>USA</td>
<td>1973-2018</td>
</tr>
<tr>
<td>3. BHP Billiton</td>
<td>Australia</td>
<td>1955-2018</td>
</tr>
<tr>
<td>4. CNX Resources (CONSOL)</td>
<td>USA</td>
<td>1864-2018</td>
</tr>
<tr>
<td>5. Contura (rebranded Alpha NR; acq Massey Jun11)</td>
<td>USA</td>
<td>1981-2018</td>
</tr>
<tr>
<td>6. Cloud Peak (added 2019)</td>
<td>USA</td>
<td>2009-2018</td>
</tr>
<tr>
<td>8. Glencore</td>
<td>Switzerland</td>
<td>1998-2018</td>
</tr>
<tr>
<td>9. Kiewit Mining</td>
<td>USA</td>
<td>1944-2018</td>
</tr>
<tr>
<td>10. Murray Energy</td>
<td>USA</td>
<td>1988-2018</td>
</tr>
<tr>
<td>11. North American Coal</td>
<td>USA</td>
<td>1950-2018</td>
</tr>
<tr>
<td>12. Peabody Energy</td>
<td>USA</td>
<td>1945-2018</td>
</tr>
<tr>
<td>13. Rio Tinto</td>
<td>UK</td>
<td>1961-2018</td>
</tr>
<tr>
<td>14. RWE</td>
<td>Germany</td>
<td>1965-2018</td>
</tr>
<tr>
<td>15. Sasol</td>
<td>South Africa</td>
<td>1953-2018</td>
</tr>
<tr>
<td>16. VistraEnergy (Luminant)</td>
<td>USA</td>
<td>1977-2018</td>
</tr>
<tr>
<td>17. Westmoreland Mining</td>
<td>USA</td>
<td>1854-2018</td>
</tr>
<tr>
<td><strong>Non-extant, acquired, oil company owned coal assets, or defunct companies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. BP</td>
<td>UK</td>
<td>1960-2003</td>
</tr>
<tr>
<td>20. Chevron Mining</td>
<td>USA</td>
<td>1965-2012</td>
</tr>
<tr>
<td>22. ExxonMobil</td>
<td>USA</td>
<td>1970-2002</td>
</tr>
<tr>
<td>24. Occidental (Island Creek Coal)</td>
<td>USA</td>
<td>1945-1992</td>
</tr>
<tr>
<td>25. RAG</td>
<td>Germany</td>
<td>1989-2003</td>
</tr>
<tr>
<td>27. UK Coal (defunct Dec15)</td>
<td>UK</td>
<td>1995-2015</td>
</tr>
</tbody>
</table>

Inventorists must pay attention to the rank of coal each company produces per year, and, if available, mining type (surface or underground). Coal rank is often reported in generic terms, such as “thermal coal” or “steam coal,” but often with data on heat content or ranks such as bituminous or subbituminous. These have varying carbon contents (from ~33% to ~73% by weight), and thus differing emission factors; see Annex A. Each worksheet also shows coal production by coal rank, or generic, in percent of coal per rank, which is linked to SumCoal.xls worksheet, which aggregates coal production history for each company and estimates emissions in “Coal Emissions” that accounts for varying emission factors. The methodology is built into the entity and summary worksheets, and no changes need be made unless one updates the distribution of coal mined by rank with revised data.

Data entry: an example: Peabody (BTU)

Peabody’s coal production worksheet (in “PeabodyXstrata.xls”) is shown in Fig 10, with details of 2018 in Fig. 11, along with our cell note on data source Peabody Energy SEC Form 10-K for 2018, page 53: “In 2018, we produced and sold 182.1 million and 186.7 million tons of coal, respectively, from continuing operations.” We calculate based on production, not total sales, which includes brokerage on behalf of other coal producers. Peabody’s production in “Coal Production” worksheet, reported as 182.1 short tons, is converted to 165.2 Mt in 2018, along with the company cumulative production from 1945 to 2018: 6,860 Mt (Fig. 11 and 12).
Fig. 10. Peabody coal production worksheet, from CoalPeabodyXstrata.xls

Fig. 11. Detail of Peabody coal production worksheet, from CoalPeabodyXstrata.xls

Fig. 12. Detail of product-related coal emissions calculated for Peabody, from SumCoal.xls

Fig. 13 shows Peabody’s coal production percentage by rank (“thermal” and “metallurgical,” 92.9% and 7.1%, respectively, which is linked back to Peabody’s production by rank (see the bottom of Fig. 11), and applied to each year of Peabody’s coal production in Fig. 14. Also see the linked formula, based on specified production by rank, in percent, in columns “D” and “I” in Fig. 13. If Peabody’s coal production by rank is updated, then that datum is updated in the “Coal
Emissions: worksheet for Peabody, or for any company with, of course, differing coal rank percentages.

Peabody’s attributed Scope 3 production-related emissions is estimated as 358 MtCO₂ in 2018 and 14,509 MtCO₂ over its history (note: Fig 14 sums each company to 2017, not 2018).

**Fig. 13.** Detail of product-related coal emissions calculated for Peabody, from SumCoal.xls

*Screenshot detail of Peabody production of “thermal” and “metallurgical” coal in percent. Fig. 11.*

**Fig. 14.** Detail of product-related coal emissions calculated for Peabody, from SumCoal.xls

*Screenshot of Peabody’s Scope 3 emissions (bottom), and the formula (top) for calculating emissions for each rank of coal.*

**Data entry: other companies**

Some companies that meet the criteria to be included in the Carbon Majors database have different corporate structures from the IOCs.

**Kiewit** is a privately-held construction and mining company, and as such does not publish data on coal production (except for general information on lignite & subbituminous mining capacity). We therefore get data from EIA *Annual Coal Report*, Table 10: Major U.S. Coal Producers.

**RWE** (Germany) is primarily an electric & gas utility and secondarily a lignite mining company. RWE does not always provide specific production data and we have approximated production using the best information available, such as a line chart published online, or output by mine. The company announced a gradual phasing out of lignite mining in compliance with the Growth, Structural Change, and Employment Commission and projects a 15% decline in production from 2017 to 2019. We have applied an annual decrease of 7.8% from 2017 production. Verify this trend for future updates. (Note: RWE also purchases hard coal for some of its powerplants; these quantities are excluded, since the Carbon Majors database is focused on extraction rather than combustion of fossil fuels purchased from other primary producers.)

**CNX Resources** was spun off from CONSOL Energy in November 2017. Consolidation Coal has been in the business since 1864, and coal production has shrunk to 6 Mt (2018). CONSOL created CNX in the 1980s to improve mine safety by capturing methane from its mines, monetized its methane capture, and expanded into shale gas production in Marcellus and Utica, reaching total production of 468 Bcf in 2018. As of this writing, CNX’s gas and CONSOL’s coal production remain under CONSOL CNX in one worksheet and as one company. (Note: CNX production of NGL & condensate remains relatively small, at ~6 Mb, and is ignored.)
State-owned entities

There are two categories of state-owned companies relevant to the acquisition of accurate production data. Group One is the list of wholly state-owned entities, such as Saudi Aramco, Petróleos de Venezuela, National Iranian Oil Company, and Sonatrach, each with a single shareholder. Production data from many of these entities are scant, ambiguous, incomplete, tardy, or partial. Not all wholly-owned companies are equally sparse with data: Pemex and Ecopetrol do provide good data.

Group Two is comprised of companies partially owned by external investors (but the state owns at least half of all shares plus 1), such as Equinor (67%), Petrobras (64%), and China National Offshore Oil (CNOOC). This group publishes annual reports or reliable online production data. Some, such as Equinor (with US production assets), also publish Form 20-Fs.

Table 3. State-owned oil and gas companies

<table>
<thead>
<tr>
<th>Group 1 (SOEs with full or majority ≥50% govt ownership):[^2]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Abu Dhabi NOC UAE</td>
</tr>
<tr>
<td>2. Bahrain Petroleum Bahrain</td>
</tr>
<tr>
<td>3. Ecopetrol Colombia</td>
</tr>
<tr>
<td>4. Egyptian General Petroleum Egypt</td>
</tr>
<tr>
<td>5. Iraq National Oil Co. Iraq</td>
</tr>
<tr>
<td>6. Kuwait Petroleum Corp. Kuwait</td>
</tr>
<tr>
<td>7. Libya National Oil Corp. Libya</td>
</tr>
<tr>
<td>8. National Iranian Oil Co. Iran</td>
</tr>
<tr>
<td>10. Oil &amp; Natural Gas Corporation India</td>
</tr>
<tr>
<td>11. Pemex Mexico</td>
</tr>
<tr>
<td>12. Pertamina Indonesia</td>
</tr>
<tr>
<td>13. PetroChina China</td>
</tr>
<tr>
<td>15. Petroleos de Venezuela Venezuela</td>
</tr>
<tr>
<td>17. Petronas Malaysia</td>
</tr>
<tr>
<td>18. Qatar Petroleum Qatari</td>
</tr>
<tr>
<td>19. Saudi Aramco Saudi Arabia</td>
</tr>
<tr>
<td>20. Sinopec China</td>
</tr>
<tr>
<td>21. Sonangol Angola</td>
</tr>
<tr>
<td>22. Sonatrach Algeria</td>
</tr>
<tr>
<td>25. Equinor (frmly Statoil) Norway</td>
</tr>
<tr>
<td>27. Petrobras Brazil</td>
</tr>
<tr>
<td>28. Rosneft Russian Federation</td>
</tr>
<tr>
<td>29. YPF (added 2019) Argentina</td>
</tr>
</tbody>
</table>

[^2]: Aramco’s plans to float a small proportion of IPO shares (5% has been mentioned) has been pushed to 2021. The company’s valuation depends critically, as do all O&G companies, on its reserves. The company commissioned a reserve estimate from Dallas-based DeGolyer & MacNaughton, which confirmed reserves of 263 Gb of crude oil and 320 Tcf of gas. Saudi Aramco is expected to become more transparent with financial and production data than is currently the case.

[^5]: These two lists are not definitive with respect to which companies do or do not have significant private ownership.
GUIDANCE FOR STATE-OWNED OIL & GAS COMPANIES / GROUP ONE:

As we mentioned above, production data for many of these government-owned entities are often scant or partial or ambiguous, or behind paywalls (e.g., WoodMacKenzie, Rystad). We first seek production data on the companies’ websites, or Oil & Gas Journal’s OGJ100 annual reporting in September each year, or other third-party sources, such as CIA Handbook or EIA’s Country Studies series, or other sources with data that appears reliable, up-to-date, and complete. (Some sources, for example, only give combined production for crude oil and natural gas in barrels of oil equivalent (boe), which is only partially useful.

We cannot provide written guidance herein for every company and every reporting variable: the worksheets themselves provide the most thorough guidance for how to update the database and data sources. We discuss three companies to illustrate the difficulty of gathering reliable data.

Abu Dhabi National Oil Co. reported crude oil and natural gas production through 2015 (excluding condensates) but not since, except for a vague reference to a commitment to produce “a target of 3.5 million barrels of oil per day by 2018” and “producing 9.8 billion cubic feet of raw gas per day.” (ADNOC.ae) However, the company re-injects large amounts of gas to maintain reservoir pressures, and we analyze reinjection rates (with EIA data from 1990-fwd) and we estimate that 40% of ADNOC’s gas production is re-injected and 60% is either used in company operations, sold domestically, or exported. If future inventorists acquire more accurate data, or if the company supplies more complete data on production, then the database should be modified accordingly.

Saudi Aramco is the largest oil producer in the world, producing one-eighth of the world’s crude oil (~3.7 Gb in 2017). The company publishes an Annual Review, though typically a year or two later than SEC filings. The Saudi Aramco oil and gas worksheet (“OilGasSaudi_Yukos.xls”) guides inventorists through the process and identification of the correct data. For example, we account for Saudi Aramco’s production as operator of the Abu Safah offshore field shared with Bahrain, and deducts for Bahrain’s 50% share of production (150,000 of 300,000 bpd), reducing Saudi Aramco’s annual production from the reported 3,735 Mb to 3,680 Mb. The worksheet adds a reported 488 Mb of NGL production. The company’s 2017 liquids production totals 4,168 Mb (preliminary: 3,760 Mb in 2018). Fig. 15 shows cumulative liquids production of 139 Gb.

Saudi Aramco’s performance summary similarly reports ambiguous data for natural gas production — “raw gas processed” and “natural gas supplied.” We average the two as the best measure of the combustion of sold natural gas and accounts for flaring and own fuel use in company refineries, gas processing, pipelines, and co-gen plants as well as unspecified amounts reinjected to maintain reservoir pressures.

![Fig. 15. Detail of Saudi Aramco oil production, 2015-2018, from “OilGasSaudi_Yukos.xls”](https://example.com/screenshot1.jpg)

Sonatrach (Algeria) reports oil and gas production (Rapport Annuel 2017, French only). We cite production data from Oil & Gas Journal, corroborated with EIA data. Sonatrach only reports gross natural gas production, which far exceeds dry gas production as reported by EIA (6,587
Bcf and 3,302 Bcf, respectively; EIA also documents reinjected gas of ~2,900 Bcf). While we prefer to use company-reported data, in Sonatrach’s case their own data is not relevant to the quantities sold and consumed as Scope 3 product-related emissions. Company data for crude oil and condensate production (1,386 Mb) also far exceeds OGJ and EIA estimates of ~386 Mb. The Carbon Majors worksheet for Sonatrach provides guidance for data sources and calculations.

GUIDANCE FOR STATE-OWNED OIL & GAS COMPANIES / GROUP TWO
Annual Reports and/or 20-F reports are readily available from the company website (see each company’s online page for “Investors / Annual Reports,” Operations data, Factbooks, and the like). Be sure of the units reported, and whether current years are consistent with prior years’ reporting. Also note, in cell notes, the data source, any uncertainties or discontinuities in the data set for crude oil, NGL, or natural gas. If there are discontinuities, research the possible reasons, such as sale of productive assets, purchase of oil or gas in the ground, new platforms or fields coming online, shutdowns, or other reasons. While Gazprom, Rosneft, and CNOOC do not file reports with SEC, each company provides comprehensive and (presumably) reliable data on net production of oil & gas.

The worksheet for each company provides guidance on the process of updating production data and the informational sources needed.

GUIDANCE FOR STATE-OWNED COAL PRODUCERS

Table 4. State-owned coal

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Coal India (78% SOE)</td>
</tr>
<tr>
<td>3.</td>
<td>Singareni Collieries (100% SOE)</td>
</tr>
</tbody>
</table>

Coal India (71% state-owned) produces bituminous and subbituminous coal. The company publishes comprehensive data on production (although its reserve estimates have been challenged) on its website, www.coalindia.in, available in translation, go to “performance / physical” for data (their fiscal calendar is such that we enter their FY2019 data for 2018).

Singareni Collieries Ltd. is also government-owned (49% Union government and 51% State of Telangana), and production data is available in a timely fashion (www.scclmines.com). One factor that may be reviewed and revised is the quality of Indian coal — typically high ash content and low heat content. Still, the EIA ranks Indian coal as predominantly bituminous (~93%) and lignite (~7%), with modest metallurgical coal resources. CAI conservatively applies the subbituminous coal emission factor (1.81 tCO2/t) rather than the bituminous EF (2.44 tCO2/t); this may be revised by future inventorists, if warranted and documented. Both Coal India and Singareni coal is assumed to be subbituminous, except for stated lignite and metallurgical production.

British Coal, though the major UK coal producer until it was privatized in 1994, does not require updating. Furthermore, its large historical emissions (17.6 GtCO2e, 1.15% of global) have not been attributed to extant coal producers due to lack of reliable information on the distribution of its assets when privatized.

Coal production history of Former Soviet Union is based on U.S. Bureau of Mines 1930-1959 and U.S. Energy Information Administration from 1960 to the dissolution of the Soviet Union in 1991, and cross-checked with United Nations data. Similarly for Czechoslovakia, although the dataset starts in 1938 when production was a substantial 32 Mt; if earlier records are found the
dataset can be extended. (FSU production was 16 Mt in 1900.) Production histories can be extended, data-gaps covered, or coal types improved in order to have a more accurate and complete accounting.

**GUIDANCE FOR NATION-STATE / GOVERNMENT-OPERATED COAL PRODUCERS**

<table>
<thead>
<tr>
<th>Table 5. Government-operated: oil, gas, coal, cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. China (coal 1945- and cement 1928-) 1945-2018</td>
</tr>
<tr>
<td>2. Czech Republic (coal) 1993-2018</td>
</tr>
<tr>
<td>3. Czechoslovakia (coal; see Czech Rep.) 1938-1992</td>
</tr>
<tr>
<td>5. Kazakhstan (coal) 1992-2018</td>
</tr>
<tr>
<td>6. North Korea (coal) 1980-2018</td>
</tr>
<tr>
<td>7. Poland (coal) 1913-2018</td>
</tr>
</tbody>
</table>

Datasets for the extant countries can also be improved with further research. China’s dataset, for example, starts in 1945 (China Mining Association) at 6 million tonnes (Mt), North Korea’s in 1962, Ukraine’s in 1992, and Poland in 1912. However, member countries of the USSR, such as Poland, Kazakhstan, and Ukraine, all with long coal mining histories, but whose production is subsumed in the FSU data. These countries thus begin their independent histories in 1992, after the collapse of the Soviet Union.

Updates of extant government-operated coal mining sectors — PRC China, Czech Republic, Kazakhstan, Poland, Russian Federation, and Ukraine — are based on country data in the U.S. Energy Information Administration’s *International Energy Statistics* and corroborated with BP’s *Statistical Review of World Energy*. BP’s highly useful publication is normally released in June of the following year, and thus a year earlier than the EIA data. The exception is North Korea, which is not afforded an entry in BP’s statistics, and we rely on the U.S. Geological Survey’s *Minerals Yearbook*, the international version of which is usually three or four years late. The latest data available for North Korea is for 2015, released in October 2018.

Country-level production data is one thing. Selecting the appropriate emission factor depends on reliable data on rank or heating value of mined coal within each country or company. We rely on extensive data on coal mined by coal rank — lignite, subbituminous, bituminous, and anthracite — published by EIA, typically from 1960 to the present; BP’s data does not distinguish coal ranks. For companies that do not report production by rank but in generic categories such as “thermal coal,” “utility coal,” or “metallurgical coal,” we use the emission factors reported in Annex A; see the *Methods and Results Report* for a thorough discussion of the derivation and sources for these emission factors.

**Cement producers**

Quantifying emissions from cement manufacture is complicated by the fact that no company (as far as we know) reports *process emissions* separately from combined emissions from calcining and industrial heat input (either direct firing or electricity). Calcining, the manufacturing process of converting limestone (CaCO3) into cement at high temperatures, liberates CO2. In order to avoid double-counting the use of fossil fuels by electric utilities or directly into cement kilns our methodology calls for estimating process emissions only. While heating ~4 billion tonnes of material to ~1,450 °C requires a lot of energy (gas, coal powder, pet coke, oil, used tires, biomass waste), our methodology *excludes* the energy-related emissions from process emissions.
The methodology, in brief, takes company-reported emissions (the sum of fossil heat inputs and process emissions) and estimates the fraction of process emissions; the methodology is based on efficiency and energy substitution improvements in the cement industry, which has increased the proportion of net CO₂ emissions (net of gross emissions: net plus emissions from energy inputs) from a prevailing 55% in the 1980s to nearly 70% today while the net emission rate has declined. The effect is that calcination emissions are declining per tonne of Portland cement. Until the industry reports process emissions separately the best we can do is use the methodology developed to estimate each company’s process emissions. Future inventorists are welcome to research and adopt improvements to this methodology. (WBCSD’s Cement Sustainability Initiative was partially transferred to Global Cement and Concrete Association in 2019.)

All companies included in our short list of major cement producers, which has shrunk through recent mergers and acquisitions, report “absolute net CO₂ emissions (Mt),” as for Cemex (Fig. 16), which is entered on the entity worksheet, which in turn is linked to the “Cement Net Emissions” worksheet in the SumCement.xls workbook, which in turn automatically calculates process emissions for each company. The data input is straight-forward, once you find the data in the company Annual Report (typically in the back of the report, “non-financial information” or similar). The linked worksheets will complete the calculation.

**Fig. 16.** Cemex net emissions, million tonnes CO₂

China’s emissions data are taken from the U.S. Geological Survey’s Minerals Yearbook, country section on China, table of minerals production. This yearbook is typically two years behind. Other more current and independent data sources are available.

**Table 6. CEMENT COMPANIES**

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Cemex Mexico</td>
<td>1990-2018</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>China (cement)</td>
<td>China 1928-2018</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>HeidelbergCement Germany 1990-2018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Holcim (merged w Lafarge) Switzerland 1990-2018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Italcimenti (acq. by Heidelberg Oct16) Italy 1990-2018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Taiheiyo Japan 1975-2018</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Calculating scope 1 direct emissions and summing cumulative emissions**

CAI has created a separate set of worksheets — one for each entity (103 as of this writing) — to summarize product-related Scope 3 emissions from oil, gas, coal, and cement. These worksheets are also used to calculate all Scope 1 direct operational emissions of carbon dioxide (from vented CO₂, combustion from own fuel use, and flaring) as well as fugitive and vented methane from oil and gas operations and coal mining. As explained above, these emission factors are based on recognized international sources (IPCC, EPA, United Nations, IEA, etc. Heede 2014, 2019).
Climate modelers require data inputs by company, by gas (CO2 and CH4), and by year. This set of worksheets and their summary sheet (Fig. 17 and Fig. 18) provide these data for each and every entity.

**Fig. 17.** Detail of Chevron’s product and operational emissions, in “EntitiesAbuDhabi-Czech.xls”

All worksheets are dynamically linked from their source worksheets (SumOil.xls, SumGas.xls, SumCoal.xls, and SumCement.xls) to each entity worksheet (Fig. 17) and summed in “SumEach&Every1850-2018 Sum Aug19.xls” (Fig. 18). An annual update simply requires to extending the data to the additional year and verifying links and sums.

**Fig. 18.** Detail of Chevron’s summary emissions by gas, in “SumEach&Every1850-2018 Sum Aug19.xls”

**Cumulative sums for each and all Carbon Majors**

In addition to providing data for each entity by gas (and year), we also want to sum cumulative emissions from all sources and year for each and every entity. This is done in “SumRanking.xls” (which also contains the same cumulative data in alphabetical order), Fig. 19.

The worksheet is linked to cumulative results for each company by source, shown in the sections in Fig. 19 (Oil, Gas, Coal & Cement, and summed, respectively). This worksheet also quantifies
Scope 1 emissions (emission factors are linked to the respective worksheets) for several ancillary sources, such as vented CO₂ from gas processing, CO₂ from flaring, CO₂ from use of own fuels (i.e., chiefly use of company natural gas prior to quantities of “gas available for sale”) and applied to each source fuel. Coal production is not attributed ancillary CO₂ emissions, since there is no flaring or venting of CO₂ in coal mining, and fuel used in mining equipment is chiefly diesel purchased from other vendors, which are excluded so as to avoid double-counting. All sources (except cement) are attributed methane emissions. See Methods & Results Report (Heede 2013, 2019) for details.

**Fig. 19.** Worksheet summing cumulative emissions for every Carbon Major entity, in “SumRanking.xls”

Figure 20 shows the “Sum Ranking” worksheet, with detail of Chevron summed to 2017. It is this summary data that is of greatest interest to media, and should be included in announcements of future database updates.

**Fig. 20.** Detail of cumulative emissions for Chevron, in “SumRanking.xls”

Inserting production data and supporting information in entity worksheets

While not strictly required, CAI prefers inserting screenshots of production data from company sources as described in this chapter in each company’s production worksheet. Below we show page 1 of Peabody Energy’s data entry worksheet. Figure 21 (Peabody worksheet page 2) shows additional historical production data, resources and reserves, and maps of operating regions. Pages 3 and 4 are printed cell notes of source data documentation and discussion. (These figures are not scaled for reading the details; see the Peabody PDF for details.)
Adding screenshots of company data is useful for later verification of production data or error detection and correction. This practice does not have to be continued by a new organizational database host, especially if it is determined that the data is to be imported into a new database platform.

**Fig. 21.** Peabody Energy data entry worksheet, pages 1 and 2.
Peabody's Leading Global Operations and Reserves

Peabody shipped 243.2 million tons of coal through rail, trucking, and ocean shipments in 2015 across North America, South America, Europe, Asia, Africa, and Australia.


Reserves


Notes: C&I includes "Trading and Brokerage."
Potential additions to the database

This chapter covers a number of issues related to the maintenance and updating of the Carbon Majors database — including mergers & acquisitions, making notes of companies no longer extant that were incorporated into other company emissions totals for a particular data release, maintaining archive data of current non-extant companies that were never acquired, discussion of adding new companies to the database, creating worksheets for newly added companies, linking data to summary worksheets, ranking and sorting cumulative emissions (in preparation for figures and tables), and commissioning of sums.

Expanding the list of companies

The protocol and methodology for Carbon Majors database was originally established with a threshold for inclusion of ~8 MtC per year. No new companies were added until 2019 (Table 7) even though several companies had grown to meet the threshold through organic growth or mergers and acquisitions — or newly came to our attention, such as some of the companies listed in Table 8.

If future inventorists have the time and resources to expand the list of companies and document their historical production of fossil fuels, such expansion is encouraged. Note: the list below does not include recent mergers and acquisitions: Shell’s acquisition of BG, CNOOC’s acquisition of Nexen, Repsol’s acquisition of Talisman, or Lafarge’s merger with Holcim, etc.

The Climate Accountability Institute added a number of investor-owned carbon majors (plus one state-owned enterprise: PetroEcuador) in 2019. All of the entities below are fully integrated in the current database.

Table 7. Oil & gas and coal companies added in 2019

<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antero</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Chesapeake</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Cloud Peak</td>
<td>USA</td>
<td>coal</td>
</tr>
<tr>
<td>Contura</td>
<td>USA</td>
<td>coal</td>
</tr>
<tr>
<td>Exxaro</td>
<td>South Africa</td>
<td>coal</td>
</tr>
<tr>
<td>EOG</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>EQT</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Inpex</td>
<td>Japan</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Noble</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Novatek</td>
<td>Russian Federation</td>
<td>coal</td>
</tr>
<tr>
<td>Obsidian</td>
<td>Canada</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Petoro</td>
<td>Norway</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>PetroEcuador</td>
<td>Ecuador</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Pioneer</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Santos</td>
<td>Australia</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Southwestern</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>TurkmenGaz</td>
<td>Turkmenistan</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Wintershall</td>
<td>Germany</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Woodside</td>
<td>Australia</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>YPF</td>
<td>Argentina</td>
<td>oil &amp; gas</td>
</tr>
</tbody>
</table>
A number of potential new companies are listed below; this list is not comprehensive, particularly for the Russian Federation and China.

Table 8. Potential new company additions to database

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Commodity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adani Group</td>
<td>India</td>
<td>coal</td>
</tr>
<tr>
<td>Adaro Energy</td>
<td>Indonesia</td>
<td>coal</td>
</tr>
<tr>
<td>Alliance Resources</td>
<td>USA</td>
<td>coal</td>
</tr>
<tr>
<td>Astra</td>
<td>Indonesia</td>
<td>coal</td>
</tr>
<tr>
<td>Banpu</td>
<td>Thailand</td>
<td>coal</td>
</tr>
<tr>
<td>Bogatyrr Coal</td>
<td>Kazakhstan</td>
<td>coal</td>
</tr>
<tr>
<td>Bumi Resources</td>
<td>Indonesia</td>
<td>coal</td>
</tr>
<tr>
<td>Canadian Oil Sands</td>
<td>Canada</td>
<td>bitumen</td>
</tr>
<tr>
<td>China Coal</td>
<td>China</td>
<td>coal</td>
</tr>
<tr>
<td>Datong Coal</td>
<td>China</td>
<td>coal</td>
</tr>
<tr>
<td>Indika Energy</td>
<td>Indonesia</td>
<td>coal</td>
</tr>
<tr>
<td>Inner Mongolia Yitai</td>
<td>China</td>
<td>coal</td>
</tr>
<tr>
<td>Kuzbass Razrez Ugol</td>
<td>Russian Federation</td>
<td>coal</td>
</tr>
<tr>
<td>Natural Resource Partners</td>
<td>USA</td>
<td>coal</td>
</tr>
<tr>
<td>Patriot Coal</td>
<td>USA</td>
<td>coal</td>
</tr>
<tr>
<td>PennWest</td>
<td>Canada</td>
<td>oil &amp; gas</td>
</tr>
<tr>
<td>Severstal</td>
<td>Russian Federation</td>
<td>coal</td>
</tr>
<tr>
<td>Shaanxi Coal</td>
<td>China</td>
<td>coal</td>
</tr>
<tr>
<td>Shenhua Group</td>
<td>China</td>
<td>coal</td>
</tr>
<tr>
<td>Siberian Business Union</td>
<td>Russian Federation</td>
<td>coal</td>
</tr>
<tr>
<td>Siberian Coal Energy (SUEK)</td>
<td>Russian Federation</td>
<td>coal</td>
</tr>
<tr>
<td>Teck Resources</td>
<td>Canada</td>
<td>coal</td>
</tr>
<tr>
<td>VostSibogul</td>
<td>Russian Federation</td>
<td>coal</td>
</tr>
<tr>
<td>Whitehaven Coal</td>
<td>Australia</td>
<td>coal</td>
</tr>
<tr>
<td>WPX</td>
<td>USA</td>
<td>oil &amp; gas</td>
</tr>
</tbody>
</table>

An unknown number of the companies listed above publish Annual Reports to shareholders and similar (presumably) reliable data on the past year’s performance. Some of the Chinese and Russian company reports are not translated into English, which poses a challenge to data collection by English speakers.

Creating new worksheets for data entry

In each workbook there are template worksheets for newly added entities. Our protocol is to enter company location and website, and a brief corporate history — either from their own website or from Wikipedia — to give readers and analysts an overview of each company, where they operate, corporate structure and ownership, and so on. A template worksheet has to be renamed and inserted alphabetically in the workbook. Reporting units and column headers may need to be revised for each new company, and a new row has to be created in the subsequent worksheets that sum production and calculate emissions.

As discussed earlier with respect to updating existing company data, we strongly urge complete citation of data sources, units, commodities extracted, details of liquids produced (crude, condensate, NGL, synthetic, bitumen, heavy oil), rank of coal produced, and so on. We also urge including a screenshot of a recent production table (from a form 10-K, say), so that database users can readily verify that the data entered for the most recent three years is accurate; Fig. 21

---

6 Climate Accountability Institute maintains a separate database in FileMaker Pro for company information, such as a running log of when updates were made, M&A activity, contact information, percent ownership by the state (if SOE), reserves, name changes, prior acquisitions, and similar information.
shows Peabody Energy’s worksheet. We often include a table of scope 1 emissions (from their Sustainability Report), a map of their operating regions, and reserves. We assiduously maintain transparency to foster verification, correction, and review. The worksheets are clearly formatted for printing and creating readable PDFs, and documentation is maintained in cell notes.

**Mergers and acquisitions**

If a company has acquired producing assets from another firm, then the subsequent annual report will reflect increased production going forward. Mergers and acquisitions require a process to account for an acquired company’s historical production (and the resulting emissions), which are attributed to the extant entity. Chevron, for example, announced the acquisition of Anadarko Petroleum in April 2019 ($65/sh), but was followed by an offer by Occidental ($70/sh). If and when the acquisition is complete, Anadarko’s previous oil and gas production and historical emissions will be added to the accounts of the acquiring company in a new column for oil and natural gas. Several mergers and acquisitions are accounted for in the existing database, such as ExxonMobil’s acquisition of XTO (2009), Exxon’s merger with Mobil (1999), Chevron’s many mergers (Standard Oil of California’s acquisition of Gulf Oil, Getty Oil, Skelly, Unocal, merger with Texaco, etc.), Royal Dutch Shell’s acquisition of BG (2016), CNOOC’s acquisition of Nexen (2013), Repsol acquisition of Talisman (2015), and so on. This is only a partial and indicative list of mergers and acquisitions.

Meanwhile, there are also acquisitions of production capacity and joint ventures to consider, but production from these assets (such as BP’s 19.75% ownership of Rosneft) is reflected in net equity production by each company and declared to shareholders and the SEC, so no special investigation is required to account for net equity production by either company, although care must be exercised to account for production by both consolidated companies and equity affiliates (e.g., Rosneft, in BP’s case), which, in our experience, is not always clear in company reporting.

When a company acquires an existing company, our procedure is to import the acquired company’s production in its own reported format (say, thousand bbl per day, or million cubic meters of gas production per year) to a new column in the acquiring company’s worksheet. And, of course, verify that the new data is added in the proper units to the summary column for the history of the acquiring company.

**Worksheets, dynamic links**

Once the history of a newly added company is complete then a new line item in the production summary sheet must be created, and dynamically linked cell for cell so that any updates (such as revisions of production data) are automatically transferred not only to production but also the resulting production-based scope 3 emissions and on down the cascading and interlinked summaries, tables, and charts.

Any #REF# cells mean that the linkage has broken or source cell has erroneous data, and the inventorist has to trace and correct the problem back to its source.

Excel functionality: see tab under Edit, “insert” / “paste special,” in which data as well as formats, formulas, cell notes, and entire series can be pasted in with a link to the document of origin. In addition, a series can be “transposed” from a column to a row, or vice versa, but in the process the links are lost.
On occasion we need to sort a column of numbers, say the cumulative emissions from a set of carbon majors, and sort by type of entity and list alphabetically. Excel cannot perform this function with data linked to other cells, so we copy the column of linked data and paste it into a column as “values.” That works fine, and the column can be sorted and manipulated in various ways, but it remains unlinked to future updates. Thus, if you do need to paste in values for this or similar reasons, mark and date the data as “pasted in” at the top of the column so that it can be re-pasted after changes of any kind are made to any of the results.

Acquiring and updating global CO₂ and CH₄
Our existing database, with companies newly added in 2019 (Table 7) has attributed 69.8% of all industrial sources of carbon dioxide (from fossil fuels and cement) since 1751 to the 103 entities in the Carbon Majors database. The historical global data, based on Rotty & Marland (1984), was compiled at U.S. DOE Oak Ridge National Laboratory’s Carbon Dioxide Information Analysis Center (CDIAC). The dataset starts with coal emissions in 1751 (at 3 MtC), adds emissions from crude oil (1870-), natural gas (1885-), cement (1928-), and flaring (1950-), in MtC per year.

The Trump administration defunded programs at ORNL, including the CDIAC database, and the dataset was transferred to the Global Carbon Project (globalcarbonproject.org) in Japan. GCP publishes annual updates to estimated global industrial emissions of CO₂ and methane, usually in the run-up to the COP in December each year. On occasion an entire data series is revised, as was recently done for cement from 1928 (Andrews, 2018).

It is important to update new editions of the global GCP dataset in conjunction with finalizing updates of the Carbon Majors so that accurate estimates of the percent of each company’s contribution — by year and cumulatively — can be made.

We also add energy-related emissions of methane, based on data published (occasionally) by the European Commission's Joint Research Centre (GHG database, 2017), but this dataset has not been updated beyond the year 2012. CAI has assumed energy-related methane emissions have been constant since 2012, at 130 TgCH₄ (3.63 MtCO₂e at GWP value of 28xCO₂, per AR4; equivalent to ~10% of global energy-related CO₂ emissions).

Summary worksheets for climate modelers
An additional set of workbooks summarize each entity’s (thus 103 worksheets) Scope 1 direct operational emissions, source by source (venting, flaring, methane, etc.), as well product-related Scope 3 emissions by fuel on an annual basis. These entity emissions are then linked to and aggregated in a worksheet that summarizes emissions of carbon dioxide and methane (as CH₄ gas) for use in climate models. This data was used as model inputs for the Ekwurzel et al. (2017) and Licker et al. (forthcoming). See Chapter 4 for discussion.
Communicating the results

There are a number of important audiences and users of this dataset: for example, analysts, lawyers, scientists and climate modelers, investigators (e.g., Attorneys General, human rights commissioners), policymakers, the companies themselves, and of course the media and the public. It is therefore important to present a credible and well-documented product, to generate comprehensible and visually striking charts and figures, and to have tables and charts freely available on the organization’s or institution’s website (or on an independent, stand-alone website). Below we show a range of existing charts and illustrations. An innovative graphic artist is welcome to explore new ways to illustrate not only the data but the role these large companies continue to play in the world. These companies have their collective hands on both the throttle and tiller on global action on climate change.

Charts and tables

**Fig. 22.** Global emissions of carbon dioxide for fossil fuel use and cement production from 1810 to 2017 (black) and the emissions attributed to 103 major carbon producers (red).

**Fig. 23.** Emissions attributed Carbon Majors and other (unattributed) producers of total CO₂ since 1751.
Fig. 24. Top Ten carbon major companies operational and product emissions 1965-2017

![Graph showing Top Ten carbon major companies operational and product emissions 1965-2017.](image1)

Fig. 25. Top Twenty carbon majors cumulative scope 1 and scope 3 emissions

![Graph showing Top Twenty companies' cumulative operations and product emissions.](image2)

Fig. 26. Top Twenty carbon majors cumulative scope 1 and scope 3 emissions

![Graph showing Top Twenty historic & potential emissions from reserves.](image3)
Table 9. Top Twenty carbon major companies operational and product emissions cumulative to 2017

<table>
<thead>
<tr>
<th>Entity</th>
<th>Product-related CO₂</th>
<th>Flaring, own fuel</th>
<th>Fugitive methane</th>
<th>Total emissions</th>
<th>Percent of global 1751-2017</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MiCO₂</td>
<td>MiCO₂</td>
<td>MiCO₂</td>
<td>MiCO₂</td>
<td>MiCO₂</td>
</tr>
<tr>
<td>1. Saudi Aramco, Saudi Arabia</td>
<td>543,364</td>
<td>1,346</td>
<td>4,723</td>
<td>54,796</td>
<td>3,40%</td>
</tr>
<tr>
<td>2. Chevron, USA</td>
<td>48,513</td>
<td>1,560</td>
<td>7,279</td>
<td>54,796</td>
<td>3,13%</td>
</tr>
<tr>
<td>3. ExxonMobil, USA</td>
<td>45,293</td>
<td>1,609</td>
<td>8,245</td>
<td>52,237</td>
<td>2,98%</td>
</tr>
<tr>
<td>4. Gazprom, Russian Federation</td>
<td>32,324</td>
<td>2,658</td>
<td>3,311</td>
<td>43,230</td>
<td>2,47%</td>
</tr>
<tr>
<td>5. BP, UK</td>
<td>35,451</td>
<td>1,136</td>
<td>3,452</td>
<td>40,039</td>
<td>2,29%</td>
</tr>
<tr>
<td>6. Royal Dutch Shell, The Netherlands</td>
<td>33,085</td>
<td>1,240</td>
<td>3,829</td>
<td>38,154</td>
<td>2,18%</td>
</tr>
<tr>
<td>7. National Iranian Oil Company</td>
<td>33,193</td>
<td>1,043</td>
<td>3,658</td>
<td>37,294</td>
<td>2,13%</td>
</tr>
<tr>
<td>8. Pemex, Mexico</td>
<td>21,058</td>
<td>669</td>
<td>1,965</td>
<td>25,692</td>
<td>1,35%</td>
</tr>
<tr>
<td>9. Coal India</td>
<td>20,070</td>
<td>0</td>
<td>2,347</td>
<td>23,126</td>
<td>1,35%</td>
</tr>
<tr>
<td>10. ConocoPhillips, USA</td>
<td>15,962</td>
<td>714</td>
<td>2,169</td>
<td>18,846</td>
<td>1,08%</td>
</tr>
<tr>
<td>11. Peabody Energy, USA</td>
<td>14,569</td>
<td>0</td>
<td>1,639</td>
<td>16,148</td>
<td>0,92%</td>
</tr>
<tr>
<td>12. Petroleos de Venezuela</td>
<td>14,412</td>
<td>401</td>
<td>1,159</td>
<td>15,980</td>
<td>0,91%</td>
</tr>
<tr>
<td>13. PetroChina, China</td>
<td>13,813</td>
<td>460</td>
<td>1,359</td>
<td>15,632</td>
<td>0,89%</td>
</tr>
<tr>
<td>14. Total, France</td>
<td>12,788</td>
<td>445</td>
<td>1,321</td>
<td>14,554</td>
<td>0,83%</td>
</tr>
<tr>
<td>15. Abu Dhabi</td>
<td>12,530</td>
<td>386</td>
<td>1,130</td>
<td>13,845</td>
<td>0,79%</td>
</tr>
<tr>
<td>16. Kuwait Petroleum Corp.</td>
<td>12,634</td>
<td>299</td>
<td>841</td>
<td>13,774</td>
<td>0,79%</td>
</tr>
<tr>
<td>17. Iraq NOC</td>
<td>11,729</td>
<td>251</td>
<td>695</td>
<td>12,675</td>
<td>0,72%</td>
</tr>
<tr>
<td>18. Sonatrach, Algeria</td>
<td>10,239</td>
<td>519</td>
<td>1,592</td>
<td>12,351</td>
<td>0,71%</td>
</tr>
<tr>
<td>19. BP, Britain</td>
<td>8,784</td>
<td>87</td>
<td>1,613</td>
<td>9,894</td>
<td>0,57%</td>
</tr>
<tr>
<td>20. CONSOL Energy</td>
<td>8,444</td>
<td>12</td>
<td>1,021</td>
<td>9,577</td>
<td>0,56%</td>
</tr>
</tbody>
</table>

Innovative graphical ways to communicate

Fig. 27. Logos of leading company emissions scaled to cumulative emissions to 2010 (top); over UK (bottom).
Creating PDFs

All worksheets are formatted for clarity and transparency, and formatted for ready-to-print PDFs. Minor adjustments to “Page Setup” and “Print Area” may be needed to capture and sequence the desired data. These settings are made in “Page Setup:” typically the scale needed for printing various worksheets to US Letter (11.5x8 inch) ranges from 40% to 60%. The large historical datasets, such as “Oil Production” (in SumOil.xls) that contain data from 1884 to the present, will be 7 to 10 pages in length, plus a page or more for cell notes (Fig. 28).

Fig. 28. Detail of Oil Production for all 72 oil producers 1937-2018; the complete PDF is 7 pp long.

Fig. 29. Detail of “Each&Every 1850-2018 Sum.xls” showing data for 15 of 103 companies for 1926-2018; the completed PDF numbers 44 formatted pages
Production worksheets for all entities are extensively documented with sources, references, and various comments. Companies with deep histories, such as the Seven Sisters oil companies, may have six or more pages of cell notes. Every page and every cell note should be captured in the finished PDF for every company and every worksheet.

Note: This has been Climate Accountability Institute’s practice. However, it may be feasible with future updates to reference the legacy PDFs through 2018 (which CAI will post by 1Q2020) and simply post emission updates for all oil, gas, coal, cement, and summary worksheets. This decreases the number of worksheets in the dataset from ~220 worksheets to ~10 worksheets. The full complement of worksheets and workbooks would remain, and accessible to researchers and scientists on request, since these are updated annually. The suggested smaller dataset for publication simplifies the publication process.

Note that for documentary reasons all worksheets should be printed with Row and Column Headings and Comments (cell notes) “At end of sheet.” PDFs do not capture the cell note “carats” shown on the worksheet (the red triangles in upper left of a cell that denotes a cell note), so including the row and column headings is the only way to locate the printed cell notes with the address. See Fig. 15, Fig. 30 and Fig. 31.

Fig. 30. Window in “Page Setup” Row & column headings and Comments “At end of sheet” are selected

![Page Setup Window](image)

**Fig. 31.** Peabody cell note documenting data source for 2018 coal production (see detail Fig. 11)

Posting results
Climate Accountability Institute has posted complete sets of entity production worksheets and all production and emissions worksheets (http://climateaccountability.org/carbonmajors.html) with data to 2010 and an update with data to 2013. CAI anticipates posting a complete update with data to 2017 in October 2019 and to 2018 in First Quarter 2020.

Open Access requests
Analysts, climate modelers, scientists, and media may request and should be given access to the entire dataset or requested subsets, in excel if requested (particularly for scientific purposes). Otherwise, CAI recommends that inquiries should be directed to posted PDFs.

Some users, such as litigants or fossil fuel companies, may request particular datasets. It has been CAI’s practice to charge for our time to assemble special datasets requested by for-profit entities.
Media & outreach
CAI freely provides information, interviews, and data to many media outlets. Some prominent media have leveraged our message and results by providing their own graphics, such as the two examples from *Science* magazine and *The Guardian*.

**Fig. 32.** Carbon Majors chart by *Science* magazine

![Carbon Majors chart by *Science* magazine](image)


**Note:** the illustrations in *Science* and *The Guardian* were both interactive online, revealing a wealth of information.

**Fig. 33.** Carbon Majors chart by *The Guardian*

![Carbon Majors chart by *The Guardian*](image)

Annex A

Emission Factors, conversions, and non-energy uses

We apply a thoroughly researched, conservative, and peer-reviewed set of emission factors. These factors and their derivation are fully described in the Methods & Results Report (Heede 2013 and 2019) and the Climatic Change paper (Heede 2014; Ekwurzel et al. 2017).

Oil, natural gas, and coal: Emission Factors

All emission factors summarized in tables A1 & A2 are embedded in the relevant worksheets. For example, in the worksheet SumOil.xls, which is linked to each company’s annual oil production (in Mb), calculates each company’s oil-related emissions (in MtCO2) by multiplying Mb times 0.3714 MtCO2/Mb. This emission factor accounts for net non-energy uses and the average composition of liquids production (~90% crude oil and ~10 NGL and condensate). Thus, Royal Dutch Shell’s net equity production of 666 Mb in 2017 converts to 247 MtCO2. Likewise, Shell’s “gas available for sale” in 2017 of 3,894 Bcf times 0.05343 MtCO2/Mb equals estimated gas-related emissions of 208 MtCO2. Shell’s oil + gas production results in end-user emissions of 456 MtCO2.

Table A1. Combustion emission factors

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Carbon tC/unit</th>
<th>Carbon dioxide tCO2/unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil &amp; NGLs</td>
<td>101.4 kgC/bbl</td>
<td>371.4 kgCO2/bbl</td>
</tr>
<tr>
<td>Natural gas</td>
<td>14.6 kgC/kcf</td>
<td>53.4 kgCO2/kcf</td>
</tr>
<tr>
<td>Lignite</td>
<td>328.4 kgC/tonne</td>
<td>1,203.5 kgCO2/t</td>
</tr>
<tr>
<td>Subbituminous</td>
<td>495.2 kgC/kcf</td>
<td>1,814.4 kgCO2/kcf</td>
</tr>
<tr>
<td>Bituminous</td>
<td>665.6 kgC/t</td>
<td>2,439.0 kgCO2/t</td>
</tr>
<tr>
<td>Anthracite</td>
<td>715.6 kgC/t</td>
<td>2,621.9 kgCO2/t</td>
</tr>
<tr>
<td>“Metallurgical coal”</td>
<td>727.6 kgC/t</td>
<td>2,665.9 kgCO2/t</td>
</tr>
<tr>
<td>“Thermal coal”</td>
<td>581.1 kgC/t</td>
<td>2,129.3 kgCO2/t</td>
</tr>
</tbody>
</table>

Crude oil: prior to non-energy deduction & adjustment for NGLs: 115.7 kgC/bbl, 423.8 kgCO2/bbl; Gas: prior to non-energy deduction: 14.86 kgC/kcf, or 54.44 kgCO2/kcf; (kcf = thousand cubic feet).

Oil, natural gas, and coal: Non-energy uses

The non-energy uses calculations are based on an analysis on gross and net crude oil and NGLs, natural gas, and coal used in production of petrochemicals, road oil, and lubricants (from refineries), fertilizers (natural gas), carbon fiber (from coal). The most complete dataset was from recurrent EPA data (EPA 2015) from 1980 to the present documenting non-energy uses and that, importantly, also calculates net volatilization to CO2 of non-energy uses (see Methods & Results Report, Heede 2013, Heede 2019 for discussion of net non-energy factors). Such net returns to the atmosphere are a significant proportion of non-energy uses, and range from near-zero for road oil (asphalt sequesters carbon quite durably) to plastics and synthetic rubber and lubricants that have substantial rates of volatilization from waste-to-energy plants (burning plastics), cement production use of tires, and routine loss of lubricants to the atmosphere in normal use. Approximately half of non-energy uses are credited back to atmospheric emissions through this analysis. The final non-energy factors are ~8.0% for liquids, less than 2% for gas and a trivial amount for coal (Table A3). See Fig. 34 and 35 for details on our calculation for net crude oil and NGL deduction for non-energy uses. Each net non-energy worksheet is in its respective workbook (SumOil, SumGas, and SumCoal).
Table A2. Petroleum products non-energy uses and net carbon storage worksheet

<table>
<thead>
<tr>
<th>Product</th>
<th>Percent net non-energy use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude oil and NGLs</td>
<td>8.018%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.856%</td>
</tr>
<tr>
<td>Coal</td>
<td>0.016%</td>
</tr>
</tbody>
</table>

Fig. 34. Petroleum products non-energy uses and net carbon storage worksheet

See Methods & Results Report for additional discussion of net non-energy uses.

Fig. 35. Calculation of final emission factor for petroleum (“Oil Emissions Factor Calc” in SumOil.xls)

See Methods & Results Report for additional discussion of emission factors for oil, gas, and coal.
Annex B

Direct operational (scope 1) emission sources

The rationale, data sources, and derivation of the values for operational Scope 1 emission sources applicable to the supply chains of oil, natural gas, and coal producers from drilling and extraction to transportation and refining (or mining and beneficiation in the case of coal) is fully described in the Methods and Results Report (Heede 2013, 2019).

Scope 2 emission sources (chiefly from purchased electricity and steam), though commonly included in company GHG inventories, are excluded from the Carbon Majors boundary definition insofar as the carbon fuels that third party utilities burn in their plants are accounted for by the primary producers. The methodology thus avoids double-counting of Scope 2 indirect emission sources.

Scope 1 emissions: crude oil & NGL

This project has quantified the production of 1,176 billion barrels of crude oil and natural gas liquids (NGLs) by 72 investor-owned and state-owned entities from as early as 1884 (ExxonMobil, then Standard Oil) to 2017. Scope 3 product-related emissions totaled 437 GtCO\textsubscript{2}, or 78.5% of global oil and NGL emissions of 556 GtCO\textsubscript{2} from 1870-2017.

Three additional factors are added to cumulative emissions for each entity: CO\textsubscript{2} from flared associated gas, vented CO\textsubscript{2}, and fugitive emissions of methane (CH\textsubscript{4}) from crude oil & NGL production, transportation, refining, storage, and distribution. The methodology for each factor is detailed in the Methods & Results Report (Heede 2013, 2019). The methodology deducts for net non-energy uses of oil and NGL prior to applying the Scope 1 emission factors.

The Scope 1 emission sources total 32 GtCO\textsubscript{2} for all Carbon Majors oil producers to 2017, including 24 GtCO\textsubscript{2}e of leaked and fugitive methane.

Scope 1 emissions: natural gas

This project has quantified the extraction of 2,973 trillion cubic feet (Tcf) of natural gas by 74 entities from 1900 (for ExxonMobil, then Standard Oil) to 2017. Product-related emissions totaled 159 GtCO\textsubscript{2}, equivalent to 71% of global gas emissions of 223 GtCO\textsubscript{2} 1885-2017.

Once non-energy uses for natural gas are accounted for, and the carbon content and emission factor is applied to each entity’s production (generally marketed production), we estimate emissions of carbon dioxide attributable to each entity. Three additional factors are added to cumulative emissions for each entity: CO\textsubscript{2} from flared natural gas, CO\textsubscript{2} vented as process emissions (especially sour gas removal: CO\textsubscript{2} and hydrogen sulfide), and routine and fugitive emissions of methane from natural gas operations, processing, transportation, and storage. We add one more factor pertinent to natural gas only: estimated entity use of own fuel.\textsuperscript{7} The methodology for each factor is detailed in the Methods & Results Report (Heede 2013, 2019).

The Scope 1 emission sources total 58 GtCO\textsubscript{2}e for all Carbon Majors gas producers to 2017, including 44 GtCO\textsubscript{2}e of methane.

\textsuperscript{7} Estimated for natural gas only insofar as the industry produces more natural gas than is “available for sale,” and while many producers re-inject produced gas into their producing oil fields in order to maintain reservoir pressures, all oil and gas producers consume a lot of natural gas in field operations, power generation, refineries, chemical plants, pipelines, etc.
Scope 1 operational emission factors are developed in and linked to “AncillaryCH4&CO2.xls”

Scope 1 emissions: coal
This project has documented the production of 209 billion tonnes (Gt) of coal production through 2017 to the Carbon Major entities and estimated cumulative emissions of 461 GtCO₂ from combustion of the produced coal. Once non-energy uses for coal are accounted for, and the carbon content and emission factor is applied to each entity's production, the emissions of carbon dioxide attributable to each entity are estimated. One more emission source is added to each entity: vented and fugitive emissions of methane from coal mining operations, the majority of which are from underground mines that are ventilated for safety reasons. Underground coal deposits contain higher proportions of methane embedded in the coal seams (methane content typically increases with coal seam depth) than surface coal deposits, where much of the trapped CH₄ has been liberated over the eons. The methodology is detailed in the Methods & Results Report (Heede 2013, 2019).

Scope 3 product-related emissions totaled 461 GtCO₂, equivalent to 62% of global coal emissions of 742 GtCO₂ from 1751 to 2017.

The Scope 1 emission sources total 52 GtCO₂ for all Carbon Majors coal producers to 2017.

Scope 1 emissions summary
In Table B1 we add the ancillary emissions of estimated vented CO₂ (from gas processing), flaring (a common practice for both safety and stranded production reasons), a conservative factor for own fuel use (natural gas for its power generation, field use, offshore production platforms, pipelines, processing plants, and refineries), and a factor for leaked and fugitive...
methane (CH₄). These ancillary emission sources are calculated in separate worksheets, fully footnoted and characterized, drawing on internationally-recognized sources such as the IPCC, IEA, US EPA, and others. See a full description of their sources, derivation, and values in the *Methods & Results Report* (Heede 2013, 2019). Note: we have converted each emission factor to kgCO₂ or kgCO₂e per tonne of CO₂ from combustion of carbon fuel, by fuel source.

In Shell’s case, these sources add 23.1 MtCO₂ and 2.53 MtCH₄ (equivalent to 70.9 MtCO₂e at IPCC’s AR5 global warming potential of 28xCO₂). Shell’s Scope 1 and Scope 3 emissions total 550 MtCO₂e in 2017.

**Table B1.** Emission factors for vented, flared, and fugitive carbon dioxide and methane

<table>
<thead>
<tr>
<th>Entity</th>
<th>Combustion kgCO₂/tCO₂</th>
<th>Flaring kgCO₂/tCO₂</th>
<th>Vented kgCO₂/tCO₂</th>
<th>Methane kgCH₄/tCO₂</th>
<th>Methane kgCO₂e/tCO₂</th>
<th>Total kgCO₂e/tCO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Oil &amp; NGLs</td>
<td>1.000</td>
<td>15.94</td>
<td>3.83</td>
<td>1.92</td>
<td>58.36</td>
<td>1,073.6</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>1.000</td>
<td>1.74</td>
<td>28.53</td>
<td>9.88</td>
<td>276.59</td>
<td>1,364.1</td>
</tr>
<tr>
<td>Coal</td>
<td>1.000</td>
<td>ne</td>
<td>ne</td>
<td>4.03</td>
<td>112.97</td>
<td>1,113.0</td>
</tr>
</tbody>
</table>

ne: not estimated; see text for discussion. Natural gas also includes own fuel use of 57.26 kg CO₂/tCO₂.

For crude oil and NGLs the aggregate emission factor for Scope 1 sources — flaring, vented CO₂, and fugitive and leaked methane — adds 7.36% to emissions from combustion of petroleum products. For natural gas, the ancillary sources are dominated by methane leakage, and totals 36.41% for all ancillary sources above those from combustion of the gas produced. Ancillary emissions for coal are for methane only.

The impact on different companies varies according to their resource mix. Natural gas companies have higher ancillary (operational, Scope 1) emissions than do companies that are chiefly crude oil producers. Gazprom’s ancillary emissions are 25.4% of total, whereas Saudi Aramco’s Scope 1 are 8.74% of total; ENI, with a more balanced portfolio, has Scope 1 at 15.6% of total. Coal producers have Scope 1 emissions (methane only) of 10.15% of total. While coal producers use large amounts of diesel and similar fuels in mining and transportation, these are purchased fuels, and thus excluded to avoid double-counting. (Note: own fuel use is included for oil and gas producers insofar as they use natural gas or petroleum fuels derived *from their own operations*, prior to sale, such as “natural gas available for sale.”)

**Fig. 37.** Scope 1 flaring and venting rates in “AncillaryCH4&CO2.xls” and linked to all Scope calculations

The *average* carbon producer in our inventory, including seven cement producers with zero ancillary emissions, has scope 1 emissions at 11.5% of total.

Since these default factors are built into the methodology, none of these factors need be revised in this or future updates.

Scope 1 operational emission factors are developed in and linked to the worksheets in “AncillaryCH4&CO2.xls”
All of these emission factors are embedded in the worksheets and applied to each company’s production of crude oil, natural gas, and coal. See Fig. 3 in chapter 3 for a flow chart of the linked and integrated worksheets.

**Cement production: Scope 1 process-related emissions**

This project includes industrial emissions from cement manufacturing. World production of cement in 2018 totaled 4.10 billion tonnes, more than half (2.48 Gt) in China. Emissions of carbon dioxide from cement manufacture include the CO2 released from the high-temperature processing of limestone (calcium carbonate, CaCO3) into clinker, the cementitious product that makes up Portland cement. This calcining process releases ~0.498 to 0.540 tCO2/t clinker.

Emissions from energy inputs such as electricity for motors and fuel inputs such as coal, petroleum coke, natural gas, tires, plastics, and other waste products or biomass used to heat the rotary kilns to ~1,450 °C are excluded. The inventory methodology is based on limestone inputs and a careful calculation of calcining CO2 emissions, including kiln dust, and either excluding or including emissions from energy inputs, depending on whether gross CO2 are sought (such as by WBCSD Cement Sustainability Initiative and its members) or industrial CO2 from limestone decarbonation (such as by CDIAC). This project estimates only process emissions from calcining and excludes emissions from fuel and electricity inputs (which are already included in another Carbon Major’s fuel production).

Scope 1 operational emissions of our seven cement manufacturers totaled 23 GtCO2, or 60% of global cement emissions of 38 GtCO2 from 1930 to 2017.

The calcining factors are built into the SumCement.xls worksheet.

**A note on conservatism**

The Climate Accountability Institute, in developing the comprehensive methodology described herein, takes a conservative approach in selecting emission factors, selecting production data (when annual reports or SEC filings conflict with earlier reports, as they occasionally do), and in calculating net non-energy uses. For example, in developing the factor for company use of its own fuels, chiefly natural gas, we err on the conservative side by taking half of the typical difference between gross production and “gas available for sale,” which is a conservatism of approximately 9 GtCO2 over the attributed history of natural gas production.
Annex C
Product-related (scope 3, category 11) emission sources

The preponderance of emissions attributed to the major carbon producers is from the combustion of carbon fuel products provided by major carbon producers and used as intended by billions of drivers, homeowners, businesses, and industries for heat and power. This is also the innovation of the Carbon Majors project, namely to trace emissions from fossil fuel use back up the supply chain to the fossil fuel producers. The use of this dataset by analysts and climate modelers underscores the need to continue updating the dataset of attributed emissions using the original methodology (Heede 2013, 2014, 2019). This manual is designed to elucidate the necessary steps to update the existing database and add new companies.

The purpose of retaining the methodology is to have a consistent and comparable dataset for future modeling and scientific investigations. While there are possible modifications and specific improvements to reduce some of the acknowledged uncertainties and caveats of the methodology as applied to various company emissions discussed elsewhere (e.g., Griffin et al. 2017), we do not address them here. Consult the Methods and Results Report (Heede 2013, 2019) for an extensive discussion of operational emissions, data sources, and emission factors.

Scope 1 operational emissions comprise 11.5% of total attributed (Scope 1 + Scope 3) emissions. In our accounting through 2017 Scope 1 sources total 142 GtCO2e and product-related Scope 3 emissions total 1,079 GtCO2e; S1 plus S3 equals 1,221 GtCO2e. The Carbon Majors database and peer-reviewed papers were the first accounting of historical emissions traceable to the largest oil, gas, and coal companies from the carbon in primary fossil fuel production by year and type of fuel. Applying a robust and peer-reviewed methodology, this project quantified both direct operational emissions and emissions from the use of each company’s equity production of crude oil, natural gas, and coal over the history of each entity to 2010, and updated this year to 2017 (Table C1). The proportion of product-related emissions and scope 1 operational CO2 and methane emissions are shown in Table C1.

Table C1. Top Twenty carbon major companies operational & product emissions cumulative to 2017.
This methodology is based on the major carbon producers’ primary business: extraction of crude oil & NGLs, natural gas, and coal. We do not, for that reason, include companies that are chiefly refiners or distributors, such as Koch Industries, Valero, or Citgo. Based on the carbon content of each type of fuel produced and accounting for net non-energy uses of each fuel (e.g., for petro-chemicals and lubricants) the model then estimates the emissions of carbon dioxide and methane for the supply chain from extraction to end use. Unlike corporate emission inventories that often (not always) quantify Scope 3 Category 11 “emissions from sold products,” our methodology focuses on carbon in each company’s extracted carbon. This focus on well-head and the mine-mouth production and resulting emissions avoids the secondary “four-dimensional spaghetti chart” of refinery products, purchased fuels, and distribution of finished fuels. That said, most vertically-integrated multi-national oil & gas companies sell more carbon fuels than they extract. Fig. 38 of Chevron’s attributed emissions from extraction and sales illustrates a typical example.

**Figure 38.** Chevron emissions from oil & gas sales (red) vs production (blue).
Annex D

References A: General


Arrhenius, Svante (1896) On the influence of carbonic acid in the air upon the temperature of the ground, *Phil. Mag.*, vol. 41:237-


CDP (2016) *In the pipeline: Which oil and gas companies are preparing for the future?* by Tarek Soliman, Luke Fletcher, & Charles Fruitiere, Nov., 48 pp


www.globalcarbonproject.org/carbonbudget


Annex D, part 2
References B: Inventory Protocols

IPIECA OGP, 2nd Ed., 84 pp.


CDP (2018) Technical Note: Guidance methodology for estimation of scope 3 category 11 emissions for oil and gas


Intergovernmental Panel on Climate Change (2006) Guidelines for National Greenhouse Gas Inventories, IPCC,
Volume 2: Energy, Chapter 1: Introduction, Table 1.4

Intergovernmental Panel on Climate Change (in preparation) 2019 Refinement to the 2006 IPCC Guidelines for
guidelines-for-national-greenhouse-gas-inventories/

International Petroleum Industry Environmental Conservation Association (2019) IPIECA climate change reporting
framework; Supplementary guidance for the oil and gas industry on voluntary sustainability reporting,

International Petroleum Industry Environmental Conservation Association (2012) Oil and gas industry guidance on
voluntary sustainability reporting, IPIECA & API & OGP, 141 pp.

organization level for quantification and reporting of greenhouse gas emissions and removals, Geneva,
www.iso.org

Institutional Investors Group on Climate Change 2010 Global Climate Disclosure Framework for Oil & Gas
Companies, IIIGCC, Ceres, and Investor Group on Climate Change (IGCC), 9 pp.,

Oil and Gas Climate Initiative (2018) Methodological note for OGCI methane intensity target and ambition, OGCI,
6 pp.

Climate-related Financial Disclosures, 73 pp. https://www.fsb-tcfd.org/


pp. www.transitionpathwayinitiative.org

the Numbers Right (GNR), WBCSD Cement Sustainability Initiative, 20 pp.

World Resources Institute (2016) A Recommended Methodology for Estimating and Reporting the Potential

World Resources Institute and World Business Council for Sustainable Development (2011b) Corporate Value
Chain (Scope 3) Accounting and Reporting Standard, by Pankaj Bhatia, Cynthia Cummis, David Rich, Laura
Draucker, Holly Lahd, and Andrea Brown, October, 148 pp.

# Annex E

## List of entities and worksheets

<table>
<thead>
<tr>
<th>OIL &amp; NGL &amp; NATURAL GAS PRODUCERS</th>
<th>ANNO</th>
<th># OF PAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abu Dhabi NOC, UAE</td>
<td>1962-2018</td>
<td>6</td>
</tr>
<tr>
<td>Anadarko, USA</td>
<td>1945-2018</td>
<td>4</td>
</tr>
<tr>
<td>Apache, USA</td>
<td>1985-2018</td>
<td>2</td>
</tr>
<tr>
<td>Antero, USA</td>
<td>2012-2018</td>
<td>2</td>
</tr>
<tr>
<td>Bahrain Petroleum</td>
<td>1975-2018</td>
<td>4</td>
</tr>
<tr>
<td>BG Group, UK (acq by Shell Feb16)</td>
<td>1963-2015</td>
<td>2</td>
</tr>
<tr>
<td>BHP Billiton, Australia</td>
<td>1970-2018</td>
<td>4</td>
</tr>
<tr>
<td>BP, UK</td>
<td>1913-2018</td>
<td>10</td>
</tr>
<tr>
<td>Canadian Natural Resources</td>
<td>1988-2018</td>
<td>2</td>
</tr>
<tr>
<td>Chesapeake, USA</td>
<td>1994-2018</td>
<td>4</td>
</tr>
<tr>
<td>Chevron, USA</td>
<td>1912-2018</td>
<td>10</td>
</tr>
<tr>
<td>ConocoPhillips, USA</td>
<td>1924-2018</td>
<td>10</td>
</tr>
<tr>
<td>Devon Energy, USA</td>
<td>1988-2018</td>
<td>4</td>
</tr>
<tr>
<td>Ecopetrol, Colombia</td>
<td>1987-2018</td>
<td>4</td>
</tr>
<tr>
<td>Egyptian General Petroleum</td>
<td>1959-2018</td>
<td>4</td>
</tr>
<tr>
<td>EnCana, Canada</td>
<td>1987-2018</td>
<td>2</td>
</tr>
<tr>
<td>Eni SpA, Italy</td>
<td>1950-2018</td>
<td>4</td>
</tr>
<tr>
<td>EOG, USA</td>
<td>1991-2018</td>
<td>4</td>
</tr>
<tr>
<td>EQT, USA</td>
<td>1992-2018</td>
<td>4</td>
</tr>
<tr>
<td>Equinor (frmly Statoil), Norway</td>
<td>1971-2018</td>
<td>6</td>
</tr>
<tr>
<td>ExxonMobil, USA</td>
<td>1882-2018</td>
<td>14</td>
</tr>
<tr>
<td>Former Soviet Union (oil, gas, coal)</td>
<td>1949-1991</td>
<td>4</td>
</tr>
<tr>
<td>Gazprom, Russian Federation</td>
<td>1989-2018</td>
<td>6</td>
</tr>
<tr>
<td>Hess, USA</td>
<td>1958-2018</td>
<td>4</td>
</tr>
<tr>
<td>Husky Energy, Canada</td>
<td>1988-2018</td>
<td>2</td>
</tr>
<tr>
<td>Inpex, Japan</td>
<td>2004-2018</td>
<td>4</td>
</tr>
<tr>
<td>Iraq National Oil Company</td>
<td>1960-2018</td>
<td>4</td>
</tr>
<tr>
<td>Kuwait Petroleum Corp.</td>
<td>1946-2018</td>
<td>6</td>
</tr>
<tr>
<td>Libya National Oil Corp.</td>
<td>1961-2018</td>
<td>4</td>
</tr>
<tr>
<td>Lukoil, Russian Federation</td>
<td>1996-2018</td>
<td>4</td>
</tr>
<tr>
<td>Marathon, USA</td>
<td>1938-2018</td>
<td>4</td>
</tr>
<tr>
<td>Murphy Oil, USA</td>
<td>1983-2018</td>
<td>4</td>
</tr>
<tr>
<td>National Iranian Oil Company</td>
<td>1928-2018</td>
<td>4</td>
</tr>
<tr>
<td>Nexen, Canada (acq by CNOOC Jan13)</td>
<td>1959-2012</td>
<td>4</td>
</tr>
<tr>
<td>Noble, USA</td>
<td>1992-2018</td>
<td>4</td>
</tr>
<tr>
<td>Nigerian National Petroleum</td>
<td>1987-2018</td>
<td>6</td>
</tr>
<tr>
<td>NorskHydro (see Statoil)</td>
<td>1987-2006</td>
<td>2</td>
</tr>
<tr>
<td>Novatek</td>
<td>2002-2018</td>
<td>4</td>
</tr>
<tr>
<td>Obsidian, Canada</td>
<td>1996-2018</td>
<td>4</td>
</tr>
<tr>
<td>Occidental, USA</td>
<td>1958-2018</td>
<td>4</td>
</tr>
<tr>
<td>Oil &amp; Natural Gas Corporation, India</td>
<td>1959-2018</td>
<td>6</td>
</tr>
<tr>
<td>OMV Group, Austria</td>
<td>1997-2018</td>
<td>2</td>
</tr>
<tr>
<td>Pemex, Mexico</td>
<td>1938-2018</td>
<td>4</td>
</tr>
<tr>
<td>Pertamina, Indonesia</td>
<td>1959-2018</td>
<td>6</td>
</tr>
<tr>
<td>Petro, Norway</td>
<td>1999-2018</td>
<td>4</td>
</tr>
<tr>
<td>Petrobras, Brazil</td>
<td>1954-2018</td>
<td>4</td>
</tr>
<tr>
<td>PetroChina, China</td>
<td>1988-2018</td>
<td>8</td>
</tr>
<tr>
<td>PetroEcuador</td>
<td>1991-2018</td>
<td>4</td>
</tr>
<tr>
<td>Petroleos de Venezuela</td>
<td>1960-2018</td>
<td>6</td>
</tr>
<tr>
<td>Petroleum Development Oman</td>
<td>1967-2018</td>
<td>6</td>
</tr>
<tr>
<td>Petronas, Malaysia</td>
<td>1959-2018</td>
<td>6</td>
</tr>
<tr>
<td>Pioneer, USA</td>
<td>1995-2018</td>
<td>4</td>
</tr>
<tr>
<td>Polish Oil &amp; Gas, Poland</td>
<td>1998-2018</td>
<td>2</td>
</tr>
<tr>
<td>Qatar Petroleum</td>
<td>1959-2018</td>
<td>4</td>
</tr>
<tr>
<td>Repsol, Spain (acq. Talisman May 2015)</td>
<td>1964-2018</td>
<td>4</td>
</tr>
<tr>
<td>Rosneft, Russian Federation</td>
<td>1998-2018</td>
<td>4</td>
</tr>
<tr>
<td>Royal Dutch Shell, Netherlands</td>
<td>1892-2018</td>
<td>10</td>
</tr>
<tr>
<td>Santos, Australia</td>
<td>1991-2018</td>
<td>4</td>
</tr>
</tbody>
</table>
Saudi Aramco, Saudi Arabia 1938-2018 8
Sibneft, Russian Fed. (see Gazprom) 1998-2004 0
Sinopec, China 1999-2018 4
Sonangol, Angola 1959-2018 4
Sonatrach, Algeria 1964-2018 4
Southwestern, USA 1988-2018 4
Suncor, Canada 1987-2018 4
Syrian Petroleum 1968-2018 4
Talisman, Canada (acq by Repsol May15) 1992-2015 2
Total SA, France 1934-2018 4
TurkmenGaz, Turkmenistan 1997-2018 2
Unocal, USA (acq. by Chevron) 1926-2004 4
Wintershall, Germany 1998-2018 4
Woodside, Australia 1971-2018 6
XTO, USA (acq. by ExxonMobil) 1994-2009 2
YPF, Argentina 2007-2018 2
Yukos, Russian Fed. (see Rosneft) 1990-2005 2

**COAL PRODUCERS**

Alpha Natural Resources, USA (see Contura) 1999-2018 2
Anglo American, UK 1909-2018 6
Arch Coal, USA 1973-2018 2
BHP Billiton, Australia 1955-2018 4
BP, UK (see BP oil & gas) 1960-2003 0
British Coal Corporation, UK 1947-1994 2
China (coal and cement) 1945-2018 6
Cloud Peak, USA 2009-2018 4
Coal India 1973-2018 6
CNX Resources (Consol), USA 1864-2018 4
Contura, USA (rebranded; see ANR, acq. Massey) 1981-2018 6
Cyprus Minerals, USA 1969-1998 2
Czech Republic (coal) 1993-2018 4
Czechoslovakia (coal; see Czech Republic) 1938-1992 0
Exxaro, South Africa 1988-2018 4
ExxonMobil, USA 1970-2002 2
Former Soviet Union (oil, gas, coal) 1900-1991 4
Glencore, Switzerland 1998-2018 2
Kazakhstan (coal) 1992-2018 4
Kiewit Mining, USA 1944-2018 2
Massey Energy, USA (acq. by Alpha NR Jun11) 1981-2011 4
Murray Energy, USA 1988-2018 2
North American Coal, USA 1950-2018 2
North Korea (coal) 1980-2018 4
Occidental, USA (Island Creek Coal) 1945-1992 2
Peabody Energy, USA 1945-2018 4
Pittsburgh & Midway (to Chevron), USA 1965-2018 2
Poland (coal) 1913-2018 4
RAG, Germany 1989-2003 4
Rio Tinto, UK 1961-2018 4
Royal Dutch Shell (see Anglo American) 1979-1999 2
Russian Federation (coal) 1992-2018 4
RWE, Germany 1965-2018 2
Sasol, South Africa 1953-2018 2
Singareni Collieries, India 1947-2018 4
UK Coal, UK (defunct Dec15) 1995-2015 2
Ukraine (coal) 1992-2018 4
VistraEnergy (Luminant), USA 1977-2018 2
Westmoreland Mining, USA 1854-2018 4

**CEMENT PRODUCERS**

Cemex, Mexico 1990-2018 4
China (cement) 1928-2018 4
HeidelbergCement, Germany 1990-2018 4
Holcim, Switzerland (merged w Lafarge) 1990-2015 4
Italcementi, Italy (acq. by Heidelberg Oct16) 1990-2016 2
LafargeHolcim (merged Jul15), France 1990-2018 2
Taiheiyo, Japan 1975-2018 4
## Annex E, part 2
### List of entities and worksheets

### INVESTOR-OWNED: OIL & GAS

1. Anadarko, USA 1945-2018  4  
2. Antero, USA  2012-2018  2  
3. Apache, USA  1985-2018  2  
4. BG Group, UK (aq by Shell Feb16)  1963-2015  2  
5. BHP Billiton, Australia  1970-2018  4  
6. BP, UK  1913-2018  10  
7. Canadian Natural Resources  1988-2018  2  
8. Chevron, USA  1912-2018  10  
9. ConocoPhillips, USA  1924-2018  10  
10. Devon Energy, USA  1988-2018  4  
11. Encana, Canada  1987-2018  2  
12. Eni SpA, Italy  1950-2018  4  
13. EOG, USA  1991-2018  4  
14. EQT, USA  1992-2018  4  
15. ExxonMobil, USA  1882-2018  14  
18. Inpex, Japan  2004-2018  4  
20. Marathon, USA  1938-2018  4  
21. Murphy Oil, USA  1983-2018  4  
22. Noble, USA  1992-2018  4  
23. Novatek  2002-2018  4  
24. Occidental, USA  1958-2018  4  
25. OMV Group, Austria  1997-2018  2  
27. Polish Oil & Gas, Poland  1998-2018  2  
28. Repsol, Spain  1964-2018  4  
29. Royal Dutch Shell, Netherlands  1892-2018  10  
30. Santos, Australia  1991-2018  4  
31. Southwestern, USA  1988-2018  4  
32. Suncor, Canada  1987-2018  4  
33. Total SA, France  1934-2018  4  
34. Wintershall, Germany  1998-2018  4  
35. Woodside, Australia  1971-2018  6

### STATE-OWNED: OIL & GAS

1. Abu Dhabi NOC, UAE  1962-2018  6  
2. Bahrain Petroleum  1975-2018  4  
4. Ecopetrol, Colombia  1987-2018  4  
5. Egyptian General Petroleum  1959-2018  4  
6. Equinor (firmly Statoil), Norway  1984-2018  6  
8. Iraq National Oil Company  1960-2018  4  
9. Kuwait Petroleum Corp.  1946-2018  6  
10. Libya National Oil Corp.  1961-2018  4  
11. National Iranian Oil Company  1928-2018  4  
13. Oil & Natural Gas Corporation, India  1959-2018  6  
14. Pemex, Mexico  1938-2018  4  
15. Pertamina, Indonesia  1959-2018  6  
16. Petoro, Norway  1999-2018  4  
17. Petrobras, Brazil  1954-2018  4  
18. PetroChina, China  1988-2018  8  
20. Petroleos de Venezuela  1960-2018  6  
<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Year Range</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.</td>
<td>Petronas, Malaysia</td>
<td>1959-2018</td>
<td>6</td>
</tr>
<tr>
<td>23.</td>
<td>Qatar Petroleum</td>
<td>1959-2018</td>
<td>4</td>
</tr>
<tr>
<td>25.</td>
<td>Saudi Aramco, Saudi Arabia</td>
<td>1938-2018</td>
<td>8</td>
</tr>
<tr>
<td>27.</td>
<td>Sinopec, China</td>
<td>1999-2018</td>
<td>4</td>
</tr>
<tr>
<td>28.</td>
<td>Sonangol, Angola</td>
<td>1959-2018</td>
<td>4</td>
</tr>
<tr>
<td>29.</td>
<td>Sonatrach, Algeria</td>
<td>1964-2018</td>
<td>4</td>
</tr>
<tr>
<td>30.</td>
<td>Syrian Petroleum</td>
<td>1968-2018</td>
<td>4</td>
</tr>
<tr>
<td>31.</td>
<td>YPF, Argentina</td>
<td>2007-2018</td>
<td>2</td>
</tr>
</tbody>
</table>

**INVESTOR-OWNED: COAL**

1. Alpha Natural Resources, USA (see Contura) 1999-2018 2
2. Alpha Natural Resources, USA 1999-2018 2
3. Anglo American, UK 1909-2018 6
4. Arch Coal, USA 1973-2018 2
5. BHP Billiton, Australia 1955-2018 4
6. BP, UK (see BP oil & gas) 1960-2003 0
7. Cloud Peak, USA 2009-2018 4
8. CNX Resources (Consol), USA 1864-2018 4
9. Contura, USA (rebranded; see ANR, acq. Massey) 1981-2018 6
11. Exxaro, South Africa 1988-2018 4
12. ExxonMobil, USA 1970-2002 2
14. Kiewit Mining, USA 1944-2018 2
15. Massey Energy, USA (acq. by Alpha NR Jun11) 1981-2011 4
17. North American Coal, USA 1950-2018 2
18. Occidental, USA (Island Creek Coal) 1945-1992 2
19. Peabody Energy, USA 1945-2018 4
20. Pittsburgh & Midway (to Chevron), USA 1965-2018 2
21. RAG, Germany 1989-2003 4
22. Rio Tinto, UK 1961-2018 4
23. Royal Dutch Shell (see Anglo American) 1979-1999 2
24. RWE, Germany 1965-2018 2
25. Sasol, South Africa 1953-2018 2
27. VistraEnergy (Luminant), USA 1977-2018 2
28. Westmoreland Mining, USA 1854-2018 4

**STATE-OWNED: COAL**

2. Coal India 1973-2018 6
3. Singareni Collieries, India 1947-2018 4

**GOVERNMENT-OPERATED: OIL, GAS, COAL, CEMENT**

1. China (coal 1945- and cement 1928-) 1945-2018 6
2. Czech Republic (coal) 1993-2018 4
3. Czechoslovakia (coal; see Czech Republic) 1938-1992 0
4. Former Soviet Union (oil, gas, coal) 1949-1991 4
5. Kazakhstan (coal) 1992-2018 4
7. Poland (coal) 1913-2018 4

**INVESTOR-OWNED: CEMENT**

1. Cemex, Mexico 1990-2018 4
2. HeidelbergCement, Germany 1990-2018 4
3. Holcim, Switzerland (merged w Lafarge) 1990-2015 4
4. Italcimenti, Italy (acq. by Heidelberg Oct16) 1990-2016 2
5. LafargeHolcim (merged Jul15), France 1990-2018 2
6. Taiheiyo, Japan 1975-2018 4
Annex F
Glossary, definitions, and conversions

Definition of key terms:

Scope 1 sources: direct operational entity emissions from owned or leased assets and facilities such as CO₂ vented from production platforms or gas processing facilities, combustion emissions from engines and gen sets, vehicles drill rigs, company aircraft, and other equipment. Vented and fugitive methane sources are also included from pipelines, valves and seals, oil storage tanks, incomplete flaring, and thousands of CH₄ sources.

Scope 2 sources: indirect operational emissions attributed to the entity for their purchased electricity and steam from third-party external sources, such as electric utilities. CAI excludes scope 2 sources in order to avoid double-counting primary carbon produced by Carbon Majors.

Scope 3 sources: a broad range of indirect emissions, voluntarily reported, e.g., emissions from purchased goods, upstream transportation, business travel, employee commuting, end-of-life emissions of sold products, and “Use of Sold Products” (category 11). Many companies report estimated emissions from sold products (i.e., to CDP or GPI, or in company sustainability reports) using various protocols. CAI’s protocol quantifies emissions from equity extraction of carbon (such as net equity production of crude oil or natural gas or coal) discussed in chapters 3 & 4. CAI accounts for carbon sequestered in company production of petrochemicals, road oil, lubricants, waxes (net of short-term volatilization of, say, lubricants and plastics combusted in waste-to-energy plants). Many oil and gas companies purchase crude oil and petroleum products for refining and re-sale. CAI avoids counting such secondary emissions from petroleum products extracted by primary producers but refined and sold by the companies included in the Carbon Majors database.

Cement emissions: Cement companies report CO₂ emissions but typically combine emissions from fossil fuel inputs, such as coal or petroleum coke, and the CO₂ driven off in the process of cement making. The Carbon Majors methodology includes process emissions, and excludes carbon fuel inputs;

Portland cement: the cementitious product of cement kilns, acts as a binding agent in making concrete;

Calcining: high temperature treatment of limestone (CaCO₃) in a kiln reduces to lime (CaO) and CO₂;

Net equity production: production credited to an oil and gas company regardless of whether it is operated or non-operated production, on the basis of its share of production from each asset;

Operated production: production of oil and natural gas from company-operated fields or offshore platforms, and includes equity production of joint venture or production-sharing partners;

Upstream: company exploration, field operations, and production upstream from refineries and processing facilities;

Downstream: refining and processing, and storage, transportation, and distribution of petroleum products and natural gas; typically includes chemical plants and fuel retail operations;

Ranks of coal (also see Table A1):

Lignite: lowest rank of coal, low carbon content, often high ash and moisture content (up to 45%), primarily used in coal-fired powerplants; gross calorific value of less than 20 MJ/kg (US: 9 to 17 million Btu per short ton (MBtu/sht))
Sub-bituminous; medium rank coal used primarily for raising steam at powerplants, 20 to 30% moisture content, 20 to 24 MJ/kg (US: 17 to 24 MBtu/sht)

Bituminous: a dense, typically black, high rank of coal typically used in coal-fired powerplants, with moisture content less than 20%; greater than 24 MJ/kg, high carbon content

Anthracite: the highest rank of coal, chiefly used for residential and industrial applications; greater than 24 MJ/kg, high carbon content

Thermal coal: includes all coal ranks typically used for raising steam, chiefly bituminous and sub-bituminous coals, but occasionally includes lignite (see Coal India)

Metallurgical or coking coal: high-carbon solid carbonaceous residue derived from low-ash low-sulfur bituminous coal baked at high heat to drive off volatiles and used as a reducing agent in steel-making; gross calorific value greater than 24 MJ/kg (US: 24.8 MBtu/sht).

Seven Sisters: a term for the seven transnational oil companies that dominated the global petroleum industry from the mid-1940s to the mid-1970s. BP (then Anglo-American), Gulf Oil (now Chevron), Royal Dutch Shell, Standard Oil Company of California (now Chevron), Standard Oil Company of New Jersey (Esso, later Exxon, now ExxonMobil), Standard Oil Company of New York (Socony, later Mobil, ExxonMobil), and Texaco (merged with Chevron). In other words, the Seven Sisters are now Four: BP, Chevron, ExxonMobil, and Royal Dutch Shell.

Common conversion factors

| Conversion Factors | 1 tonne crude oil | 1 bbl | 1 cubic meter natural gas STP | 1 tonne | 1 tonne CO₂ (STP) | 1 tonne LNG | 1 billion tCO₂/yr | 1 gallon | 1 gram of methane |
|-------------------|-------------------|-------|-----------------------------|---------|------------------|------------|-------------------|---------|----------------|}
|                   |                   | 7.33 bbl | 42 gallons & 159 liters | 35.315 cubic feet | 1.0231 short ton | 10.3 meter diameter sphere | ~48,700 cf or ~1,380 m³ | 31.7 tCO₂/sec | 3.785 liters | 28 gCO₂ equiv. |


For climate conversions and factors, see IPCC AR5, US EPA, IPCC 2006 Guidelines.
Climate Accountability Institute
Director: Richard Heede
heede@climateaccountability.org
1626 Gateway Road
Snowmass, CO 81654 USA
970-343-0707 mobile