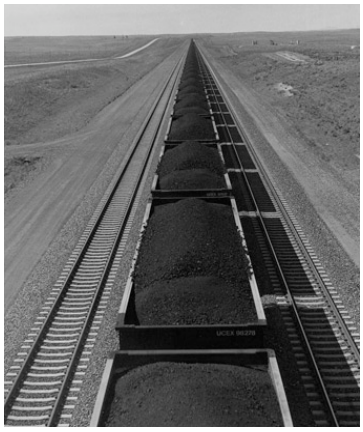
Carbon Majors:

Updating activity data, adding entities, & calculating emissions:

A Training Manual




By Richard Heede

Climate Accountability Institute

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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 CH_4 or in CO_2-equivalent terms (CO_2e; AR4: 100-y, $28xCO_2$).

Cover: Standard Oil "octopus" Udo Keppler, 1904; flaring in Nigeria, World Bank 2011; bituminous coal; coal train, Wyoming; Mountaintop removal, Kayford WV, Vivian Stockman, 2003; platform off Qatar; Jahre Viking ULCC tanker (now dismantled).

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

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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.

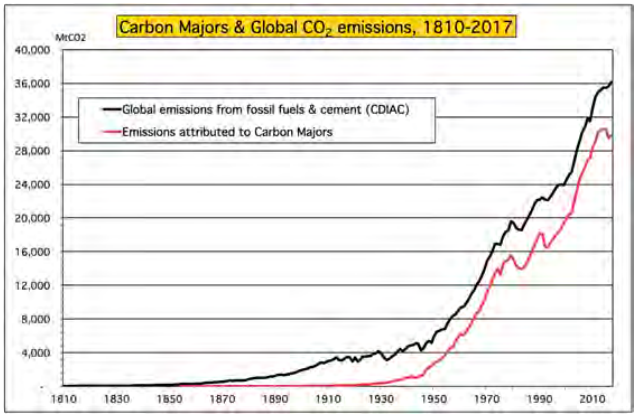
And of course I cannot survive long without the encouragement and love of my partner Karina, who has to put up with lots of late nights and long days. Bring the rum!

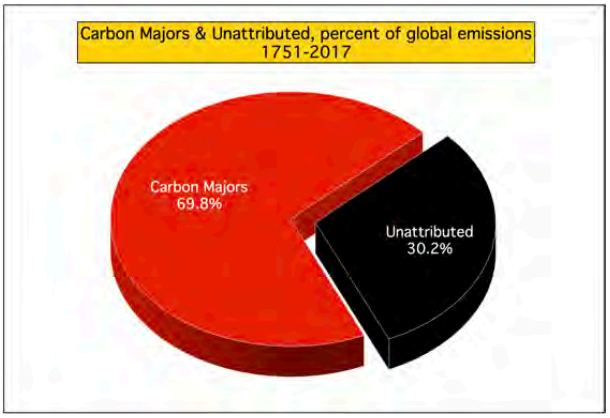
<1>
Introduction

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 *production*. Both methodologies have their uses, the former emphasizing downstream impacts, the latter upstream; we focus on the companies that *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

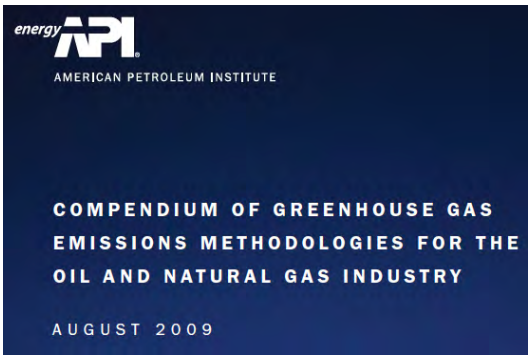
1. open access to all potential users of the database,
2. full transparency of methodology and results,
3. no paywalls for access to PDFs to all worksheets (except transactional costs for special requests and particular datasets or subsets)

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

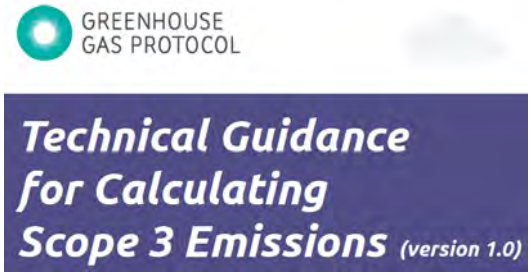
The API *Compendium* and the WRI *Protocol* focus on *operational* emissions, termed Scope 1 and Scope 2 in the *Protocol*, and are followed by most fossil fuel companies (as well as companies in other economic sectors) in exploration and production (SIC 1300s), petroleum refining (SIC 2900s), and chemicals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



Scope 1 direct operational emissions from owned, controlled, or leased assets (such as combustion emissions or flaring at refineries, CO_2 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 CO_2, $MtCO_2$), 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 CO_2: 3.664191.[2] 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, CO_2 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*15.9994)/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.

<3>

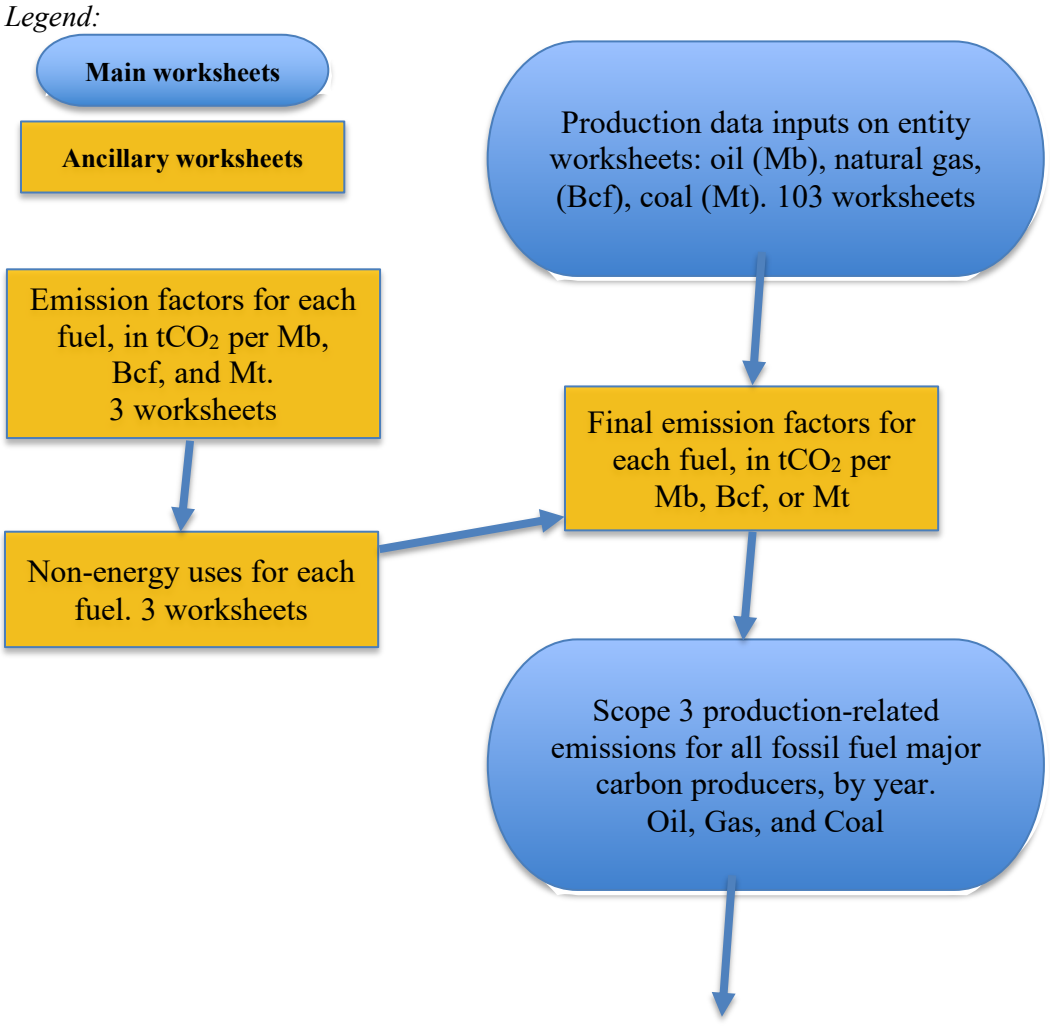
Database architecture, data sources, and updating: an overview

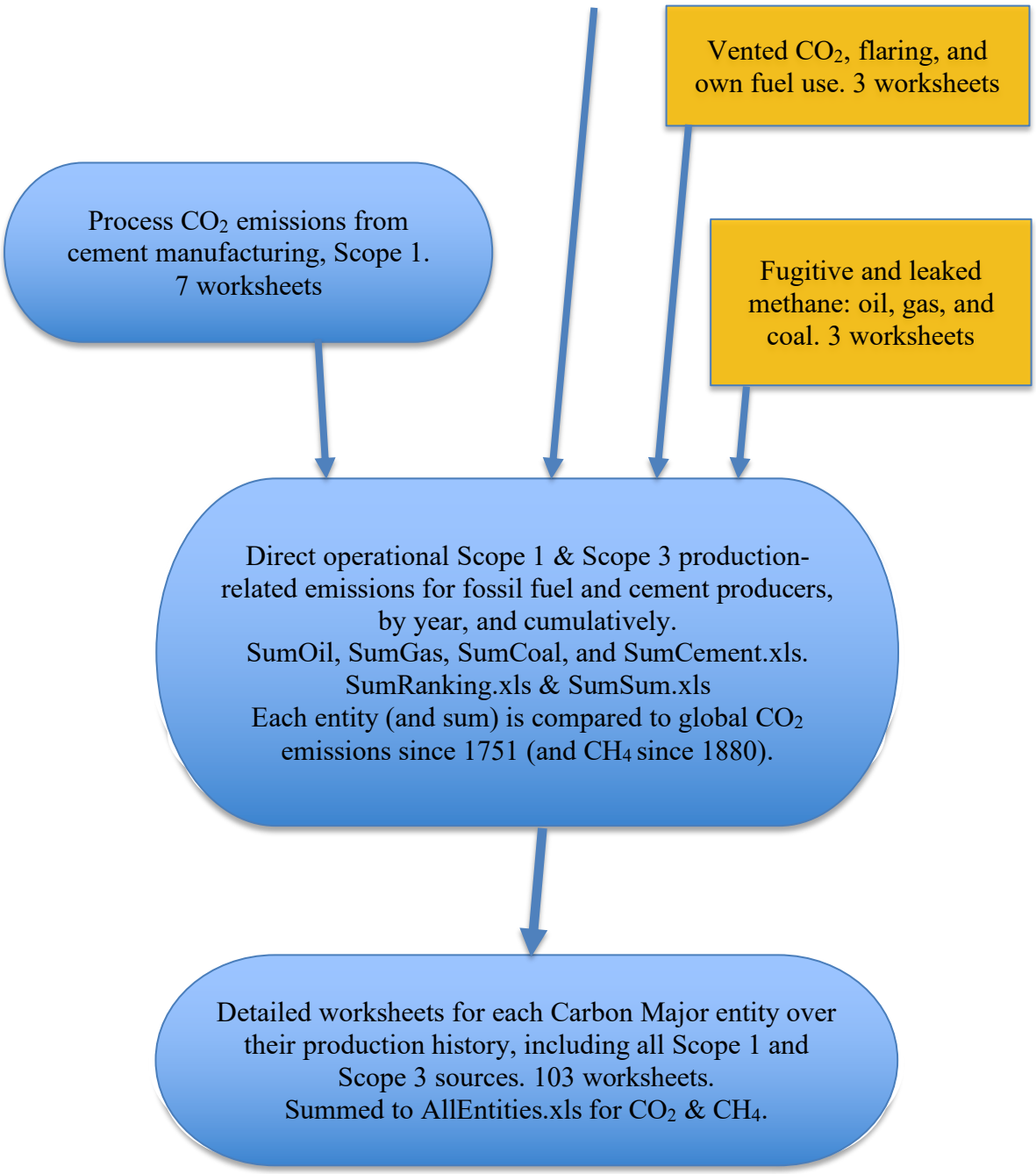
Database architecture

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 CO_2 equivalent ($TtCO_2e$) through 2017, or 69.8 percent of global fossil fuel & cement emissions (1.75 $TtCO_2e$) from 1751 to 2017.

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





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)

The best source for updating investor-owned production of oil, natural gas, and coal is the U.S. Securities & Exchange Commission's Electronic Data Gathering & Retrieval System (EDGAR):

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

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)

The current database includes nine nation-state coal producers: Former Soviet Union, Russian Federation, China, North Korea, Ukraine, Poland, China, Czech Republic, and Kazakhstan. Data sources include U.S. Energy Information Administration *International Energy Statistics*, CIA *Factbook*, U.S. Geological Survey *Minerals Yearbook*, BP *Statistical Review of World Energy*, China National Bureau of Statistics *Statistical Yearbook*, and so on.

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).

<4>

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

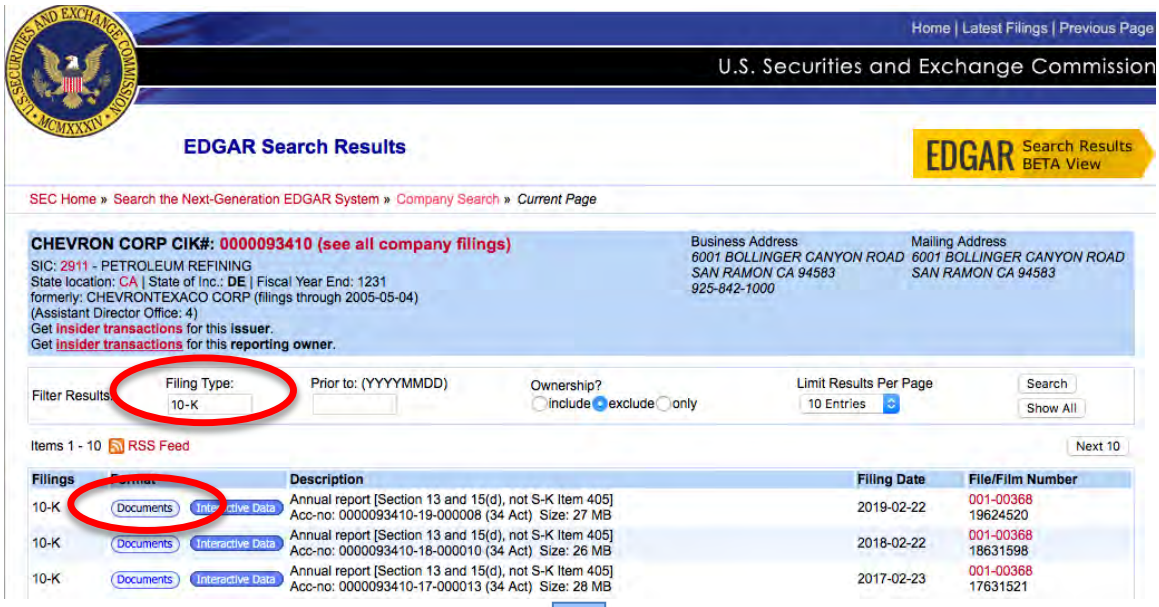
Updating investor-owned net equity production is accessible for all companies filing with the SEC at:

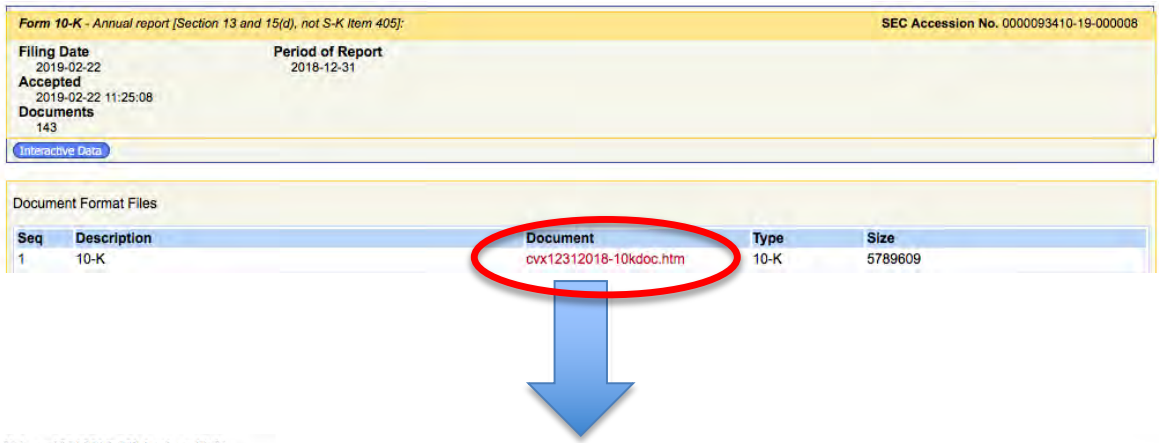
www.sec.gov/edgar/searchedgar/companysearch.html

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





10-K 1 cvx12312018-10kdoc.htm 10-K

UNITED STATES SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

Form 10-K

þ ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE
SECURITIES EXCHANGE ACT OF 1934
For the fiscal year ended December 31, 2018
OR
o TRANSITION REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE
SECURITIES EXCHANGE ACT OF 1934
For the transition period from _____ to _____
Commission File Number 001-00368

Chevron Corporation

(Exact name of registrant as specified in its charter)

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	PART III	

Screenshots of SEC EDGAR search for Chevron CVX Form 10-K and Table of Contents 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.

			Components of Oil-Equivalent			
	Oil-Equivalent		Liquids		Natural Gas	
Thousands of barrels per day (MBPD)	(MBPD)[1]		(MBPD)		(MMCFPD)	
Millions of cubic feet per day (MMCFPD)	**2018**	2017	**2018**	2017	**2018**	2017
Total Consolidated Companies	**2,483**	2,262	**1,443**	1,368	**6,244**	5,371
Affiliates[2,5]	**447**	466	**339**	355	**645**	661
Total Including Affiliates[6]	**2,930**	2,728	**1,782**	1,723	**6,889**	6,032
[1] Oil-equivalent conversion ratio is 6,000 cubic feet of natural gas = 1 barrel of crude oil.						
[2] Includes synthetic oil: Canada, net	**53**	51	**53**	51	—	—
Venezuelan affiliate, net	**24**	28	**24**	28	—	—

Screenshots of Chevron 10-K for 2018, Table of production for 2017 & 2018, page 5.

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,[3] 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*.

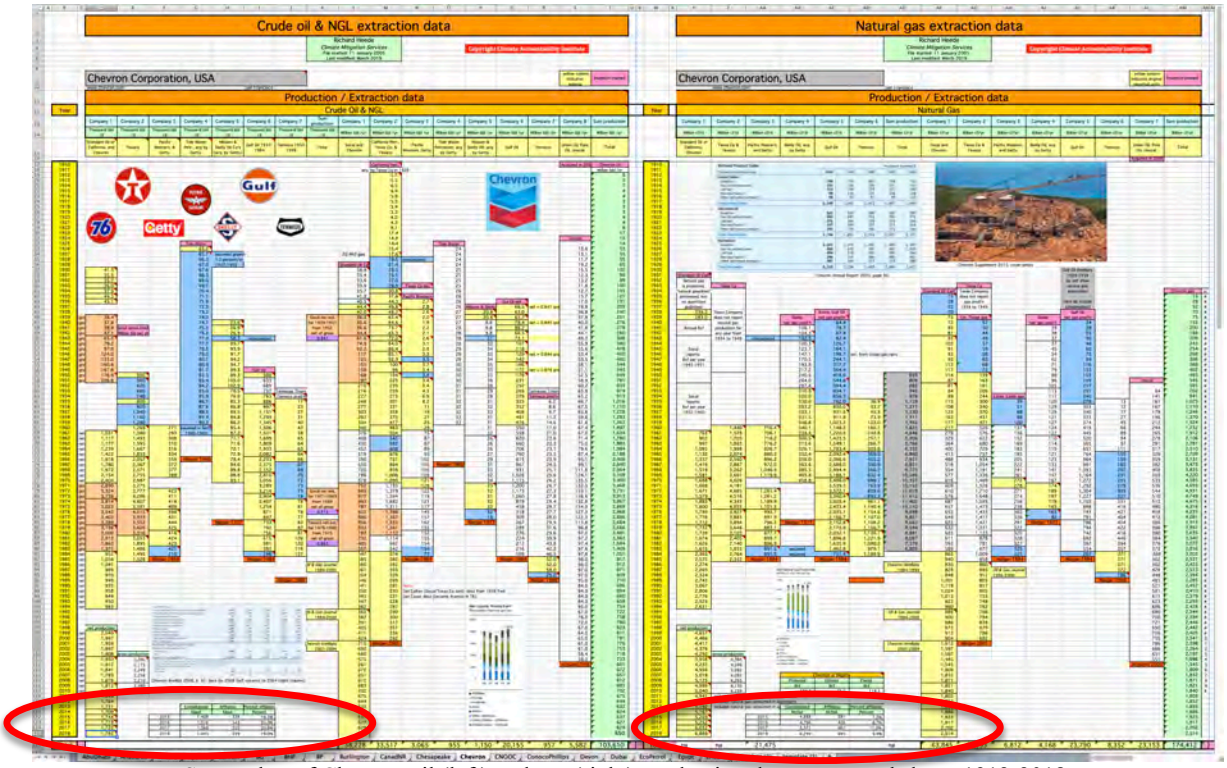
account for the higher carbon intensity of bitumen and synthetic oil, which is relevant for producers active in Athabascan oil sands, or a high proportion of NGLs and condensates, such as for Gazprom). Also note changes in reporting, such as net vs gross production (this is more pertinent in decades 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 CO_2 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)

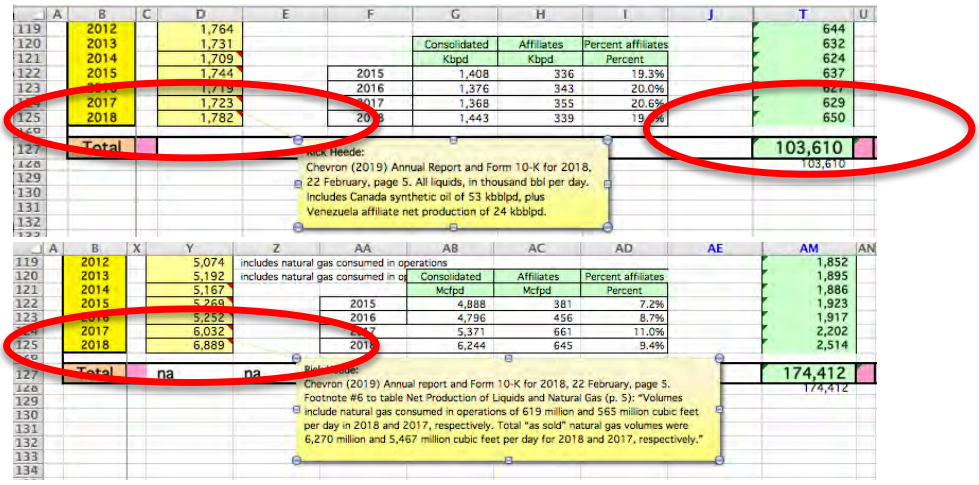
Chevron's equity production of crude oil and NGLs (thousand barrels per day, or kbpd ["MBPD" in CVX, p. 5]) and natural gas (million cubic feet per day, Mcfpd ["MMCFPD"]). Chevron's 2017 liquids production is reported as 1,723 kbpd, which, when entered in column "D" in the worksheet, is automatically 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)



Screenshot of Chevron oil (left) and gas (right) production data entry worksheet, 1912-2018.

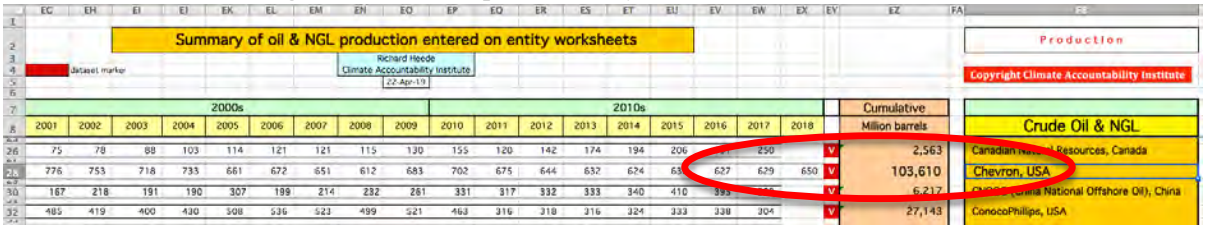
Fig. 7. Chevron data entry in OilGasAdnoc_Encana worksheet



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.

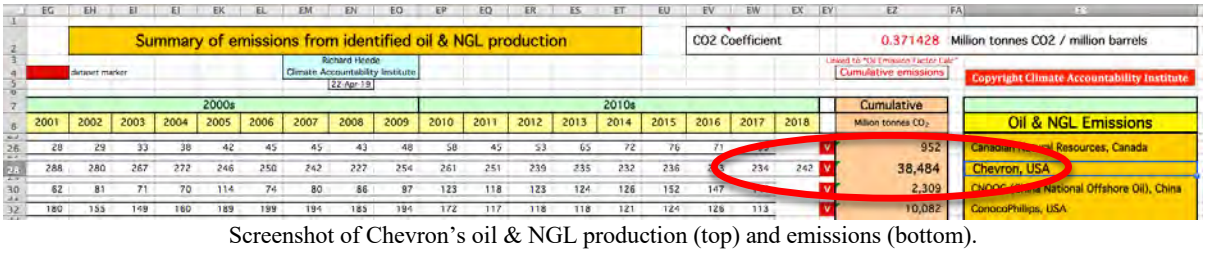
Emission factors for each fuel type are built into each respective worksheet (see Annex B). Chevron's production of crude oil and NGL (and synthetic and heavy oil) totaled 629 Mb in 2017 in "Oil Production" worksheet (Fig. 8).

Fig. 8. Detail of oil production by Chevron, from SumOil.xls



In the "Oil emissions" worksheet each company's annual production is multiplied by the emission factor of 0.3714 $MtCO_2/Mb$ (appearing in the upper right of Fig. 9, and is linked to the Emission Factor worksheet. This calculates production-related emissions of CO_2 for each company for every year. For Chevron (Fig. 9) it estimates emissions of 234 $MtCO_2$ in 2017 and, summing Chevron's production history from 1912 to 2018, estimates cumulative emissions of 38,484 $MtCO_2$. Annex A discusses the sources and derivation of emission factors and net non-energy use factors for each fuel.

Fig. 9. Detail of product-related oil emissions calculated for Chevron, from SumOil.xls



Screenshot of Chevron's oil & NGL production (top) and emissions (bottom).

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

Company	Country	Data coverage
1. Anadarko	USA	1945-2018
2. Antero (added 2019)	USA	2012-2018
3. Apache	USA	1985-2018
4. BHP Billiton	Australia	1970-2018
5. BP	UK	1913-2018
6. Canadian Natural Resources	Canada	1988-2018
7. Chesapeake (added 2019)	USA	1994-2018
8. Chevron	USA	1912-2018
9. ConocoPhillips	USA	1924-2018
10. Devon Energy	USA	1988-2018
11. EnCana	Canada	1987-2018
12. Eni SpA	Italy	1950-2018
13. EOG (added 2019)	USA	1991-2018
14. EQT (added 2019)	USA	1992-2018
15. ExxonMobil	USA	1882-2018
16. Hess	USA	1958-2018
17. Husky Energy	Canada	1988-2018
18. Inpex (added 2019)	Japan	2004-2018
19. Lukoil	Russian Federation	1996-2018
20. Marathon	USA	1938-2018
21. Murphy Oil	USA	1983-2018
22. Noble (added 2019)	USA	1992-2018
23. Novatek (added 2019)	Russian Federation	2002-2018
24. Obsidian (added 2019)	Canada	1996-2018
25. Occidental	USA	1958-2018
26. OMV Group	Austria	1997-2018
27. Petoro (added 2019)	Norway	1999-2018
28. Pioneer (added 2019)	USA	1995-2018
29. Polish Oil & Gas	Poland	1998-2018
30. Repsol (acq Talisman May 2015)	Spain	1964-2018
31. Royal Dutch Shell (acq BG Feb 2015)	Netherlands	1892-2018
32. Santos (added 2019)	Australia	1991-2018
33. Southwestern (added 2019)	USA	1988-2018
34. Suncor	Canada	1987-2018
35. Total SA	France	1934-2018
36. Wintershall (added 2019)	Germany	1998-2018
37. Woodside (added 2019)	Australia	1971-2018

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

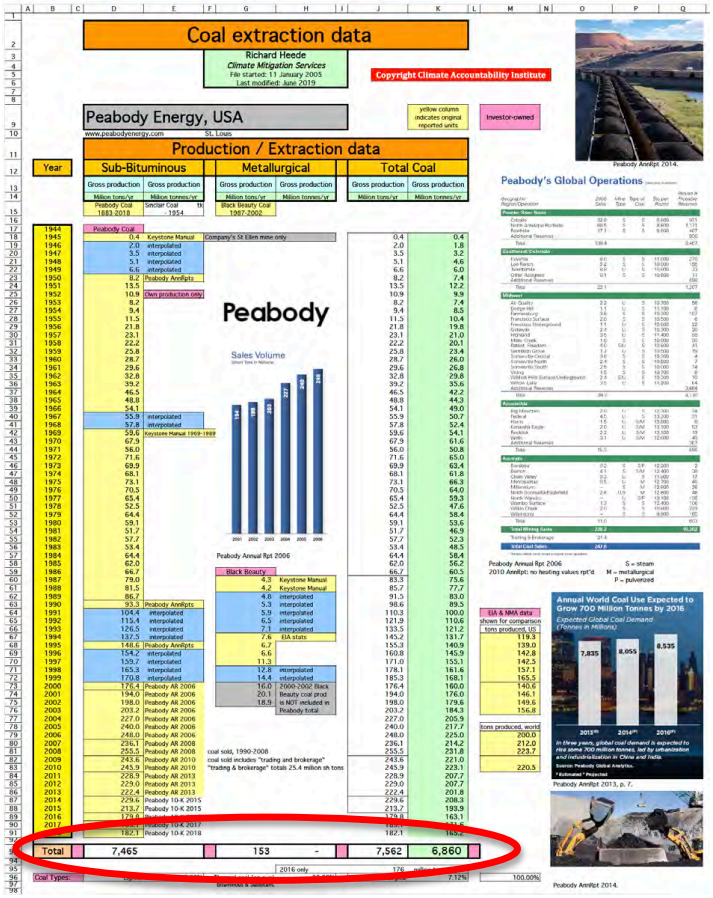
	Company	Country	Data coverage
1.	Anglo American	UK	1909-2018
2.	Arch Coal	USA	1973-2018
3.	BHP Billiton	Australia	1955-2018
4.	CNX Resources (CONSOL)	USA	1864-2018
5.	Contura (rebranded Alpha NR; acq Massey Jun11)	USA	1981-2018
6.	Cloud Peak (added 2019)	USA	2009-2018
7.	Exxaro (added 2019)	South Africa	1988-2018
8.	Glencore	Switzerland	1998-2018
9.	Kiewit Mining	USA	1944-2018
10.	Murray Energy	USA	1988-2018
11.	North American Coal	USA	1950-2018
12.	Peabody Energy	USA	1945-2018
13.	Rio Tinto	UK	1961-2018
14.	RWE	Germany	1965-2018
15.	Sasol	South Africa	1953-2018
16.	VistraEnergy (Luminant)	USA	1977-2018
17.	Westmoreland Mining	USA	1854-2018
Non-extant, acquired, oil company owned coal assets, or defunct companies			
18.	Alpha NR (acq Massey Jun 2011)	USA	1999-2011
19.	BP	UK	1960-2003
20.	Chevron Mining	USA	1965-2012
21.	Cyprus Minerals	USA	1969-1998
22.	ExxonMobil	USA	1970-2002
23.	Massey Energy (acq. by Alpha NR Jun11)	USA	1981-2011
24.	Occidental (Island Creek Coal)	USA	1945-1992
25.	RAG	Germany	1989-2003
26.	Royal Dutch Shell	The Netherlands	1979-1999
27.	UK Coal (defunct Dec15)	UK	1995-2015

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)

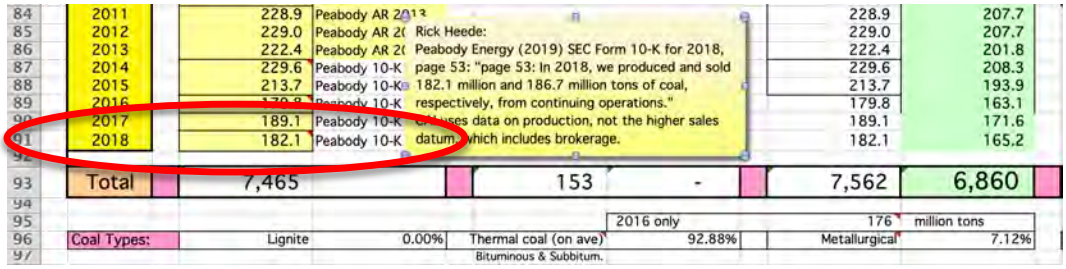
Peabody’s coal production worksheet (in “PeabodyXstrata.xls”) is shown in Fig 10, with details of 2018 in Fig. 11, along with our cell note on data source Peabody Energy SEC Form 10-K for 2018, page 53: “In 2018, we produced and sold 182.1 million and 186.7 million tons of coal, respectively, from continuing 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



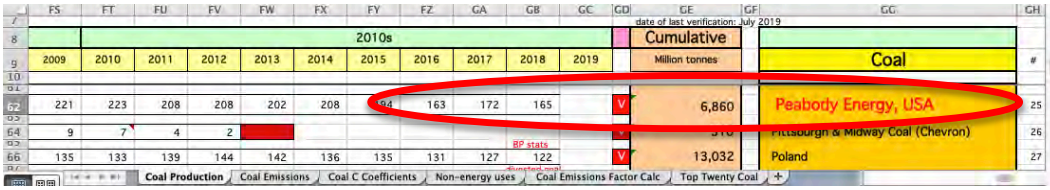
Screenshot of Peabody Energy coal production worksheet, 1945-2018

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



Screenshot of Peabody production worksheet, with cell note for 2018, production of 182 Mt, and coal by rank (bottom).

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



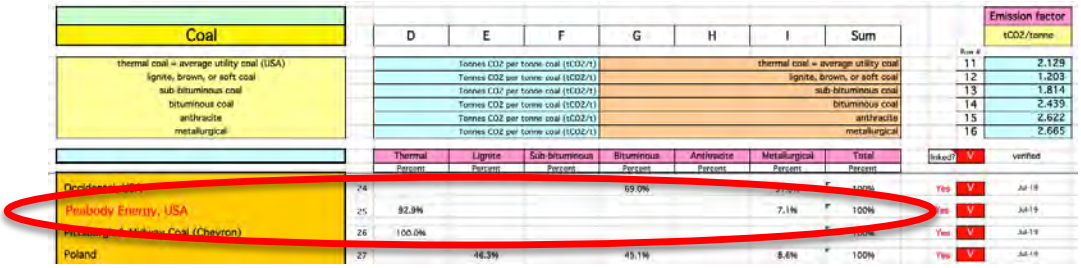
Screenshot of Coal

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.

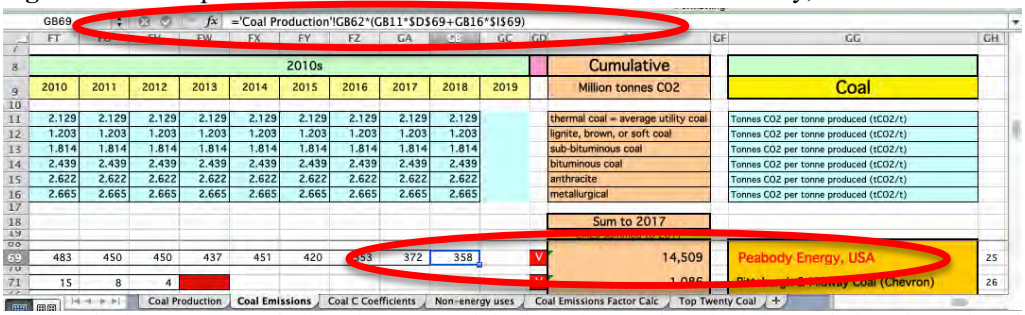
Peabody's attributed Scope 3 production-related emissions is estimated as 358 $MtCO_2$ in 2018 and 14,509 $MtCO_2$ over its history (note: Fig 14 sums each company to 2017, not 2018).

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.[4] 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

Group 1 (SOEs with full or majority ≥50% govt ownership):[5]

1.	Abu Dhabi NOC	UAE	1962-2018
2.	Bahrain Petroleum	Bahrain	1975-2018
3.	Ecopetrol	Colombia	1987-2018
4.	Egyptian General Petroleum	Egypt	1959-2018
5.	Iraq National Oil Co.	Iraq	1960-2018
6.	Kuwait Petroleum Corp.	Kuwait	1946-2018
7.	Libya National Oil Corp.	Libya	1961-2018
8.	National Iranian Oil Co.	Iran	1928-2018
9.	Nigerian National Petroleum	Nigeria	1987-2018
10.	Oil & Natural Gas Corporation	India	1959-2018
11.	Pemex	Mexico	1938-2018
12.	Pertamina	Indonesia	1959-2018
13.	PetroChina	China	1988-2018
14.	PetroEcuador (added 2019)	Ecuador	1991-2018
15.	Petroleos de Venezuela	Venezuela	1960-2018
16.	Petroleum Development Oman	Oman	1967-2018
17.	Petronas	Malaysia	1959-2018
18.	Qatar Petroleum	Qatar	1959-2018
19.	Saudi Aramco	Saudi Arabia	1938-2018
20.	Sinopec	China	1999-2018
21.	Sonangol	Angola	1959-2018
22.	Sonatrach	Algeria	1964-2018
23.	TurkmenGaz (added 2019)	Turkmenistan	1997-2018

Group 2 (SOEs with significant <50% private ownership):

24.	China National Offshore Oil/CNOOC	China	1988-2018
25.	Equinor (frmly Statoil)	Norway	1971-2018
26.	Gazprom (acq Sibneft Aug 2005)	Russian Federation	1989-2018
27.	Petrobras	Brazil	1954-2018
28.	Rosneft	Russian Federation	1990-2018
29.	YPF (added 2019)	Argentina	2007-2018

[4] 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.

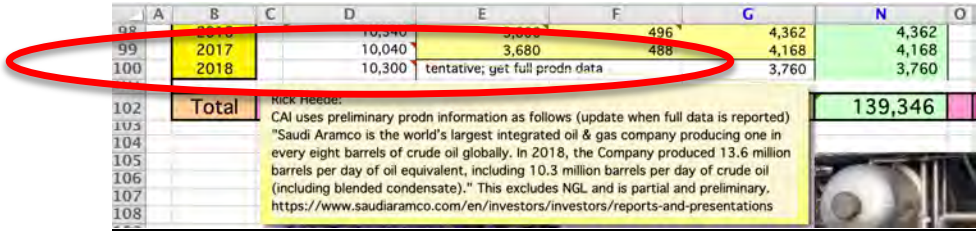
We cannot provide written guidance herein for every company and every reporting variable: the worksheets themselves provide the most thorough guidance for how to update the database and data sources. We discuss three companies to illustrate the difficulty of gathering reliable data.

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"



Screenshot of Saudi Aramco liquids production 2016-2018 (2018 is tentative).

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

1.	British Coal Corporation	UK	1947-1994
2.	Coal India (78% SOE)	India	1973-2018
3.	Singareni Collieries (100% SOE)	India	1947-2018

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 tCO_2/t) rather than the bituminous EF (2.44 tCO_2/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 $GtCO_2e$, 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 5. Government-operated: oil, gas, coal, cement

1.	China (coal 1945- and cement 1928-)	1945-2018
2.	Czech Republic (coal)	1993-2018
3.	Czechoslovakia (coal; see Czech Rep.)	1938-1992
4.	Former Soviet Union (oil, gas, coal)	1949-1991
5.	Kazakhstan (coal)	1992-2018
6.	North Korea (coal)	1980-2018
7.	Poland (coal)	1913-2018
8.	Russian Federation (coal)	1992-2018
9.	Ukraine (coal)	1992-2018

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 ($CaCO_3$) into cement at high temperatures, liberates CO_2. 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, bio-mass 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 CO_2 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 CO_2 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 CO_2

CARBON STRATEGY AND ENERGY	2016	2017	2018
Absolute gross CO_2 emissions (million ton)[8]	43.8	42.5	43.0
Absolute net CO_2 emissions (million ton)[8]	41.4	39.7	40.0
Specific gross CO_2 emissions (kg CO_2/ton of cementitious product)[8]	678	677	674
Specific net CO_2 emissions (kg CO_2/ton of cementitious product)[8]	642	636	630
Reduction in CO_2 emissions per ton of cementitious product from 1990 baseline (%)	20.1	20.7	21.6

Cemex carbon data, *2018 Integrated Report*, page 200.

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

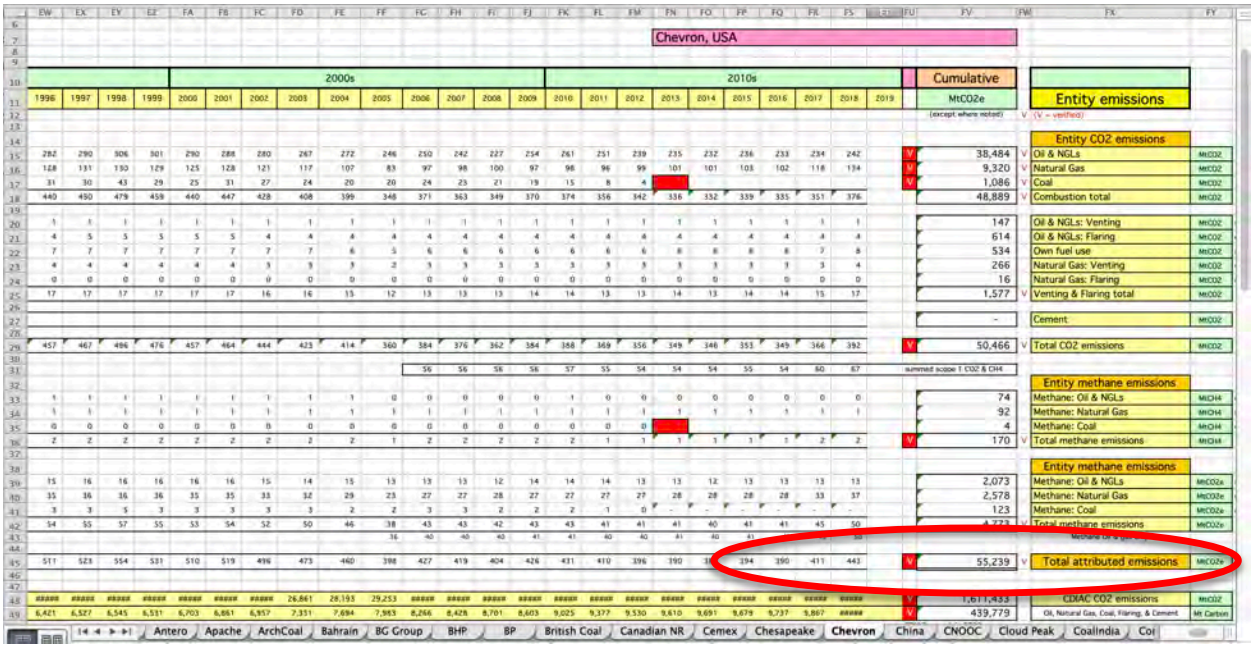
1.	Cemex	Mexico	1990-2018
2.	China (cement)	China	1928-2018
3.	HeidelbergCement	Germany	1990-2018
4.	Holcim (merged w Lafarge)	Switzerland	1990-2018
5.	Italcimenti (acq. by Heidelberg Oct16)	Italy	1990-2018
6.	LafargeHolcim (merged Jul15)	France	1990-2018
7.	Taiheiyo	Japan	1975-2018

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 CO_2, 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 (CO_2 and CH_4), and by year. This set of worksheets and their summary sheet (Fig. 17 and Fig. 18) provide these data for each and every entity.

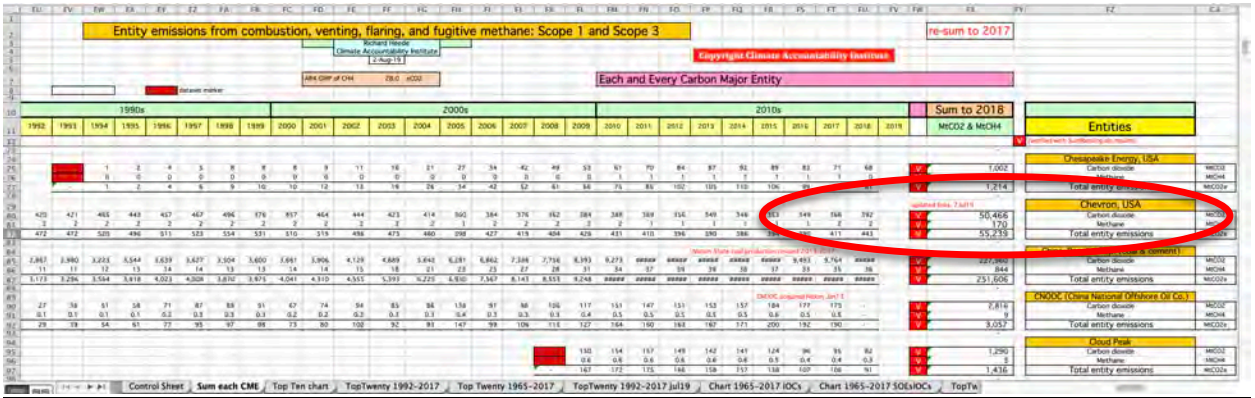
Fig. 17. Detail of Chevron's product and operational emissions, in "EntitiesAbuDhabi-Czech.xls"



Screenshot of Chevron Scope 1 and Scope 3 emissions, 1996-2018.

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"



Screenshot of Chevron CO_2 and methane emissions by gas, 1992-2018.

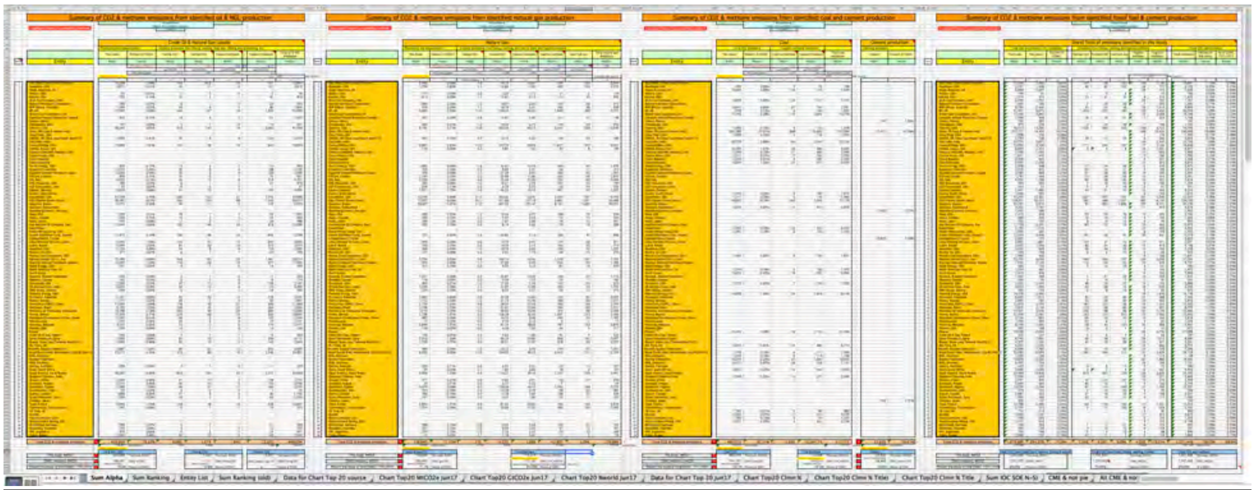
Cumulative sums for each and all Carbon Majors

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 CO_2 from gas processing, CO_2 from flaring, CO_2 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 CO_2 emissions, since there is no flaring or venting of CO_2 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.

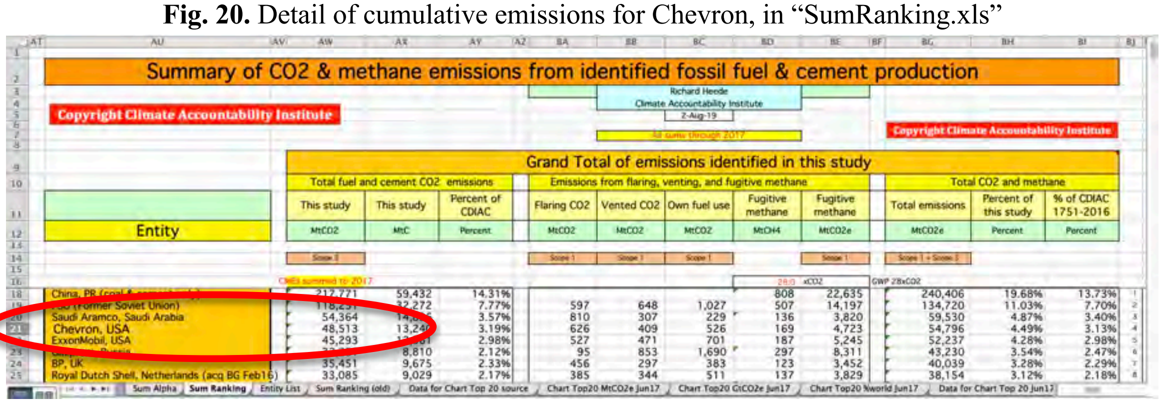
Fig. 19. Worksheet summing cumulative emissions for every Carbon Major entity, in "SumRanking.xls"



Screenshot of product-related and operational emissions for all 103 entities: oil, gas, coal, cement, and sum (left to right).

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"



Entity	This study (MtCO2)	This study (MtC)	Percent of CDIAC (Percent)	Flaring CO2 (MtCO2)	Vented CO2 (MtCO2)	Own fuel use (MtCO2)	Fugitive methane (MtCH4)	Fugitive methane (MtCO2e)	Total emissions (MtCO2e)	Percent of this study (Percent)	% of CDIAC 1751-2016 (Percent)	
	Total fuel and cement CO2 emissions			Emissions from flaring, venting, and fugitive methane					Total CO2 and methane			
	Scope 3			Scope 1	Scope 1	Scope 1		Scope 1	Scope 1 + Scope 3			
China, PR [illegible]	217,771	59,432	14.31%				808	22,635	240,406	19.68%	13.73%	1
[illegible] (Former Soviet Union)	[illegible]	32,272	7.77%	597	648	1,027	507	14,197	134,720	11.03%	7.70%	2
Saudi Aramco, Saudi Arabia	54,364	[illegible]	3.57%	810	307	229	136	3,820	59,530	4.87%	3.40%	3
Chevron, USA	48,513	13,240	3.19%	626	409	526	169	4,723	54,796	4.49%	3.13%	4
ExxonMobil, USA	45,293	[illegible]	2.98%	527	471	701	187	5,245	52,237	4.28%	2.98%	5
[illegible], Russia	[illegible]	8,810	2.12%	95	853	1,690	297	8,311	43,230	3.54%	2.47%	6
BP, UK	35,451	9,675	2.33%	456	297	383	123	3,452	40,039	3.28%	2.29%	7
Royal Dutch Shell, Netherlands (acq BG Feb16)	33,085	9,029	2.17%	385	344	511	137	3,829	38,154	3.12%	2.18%	8

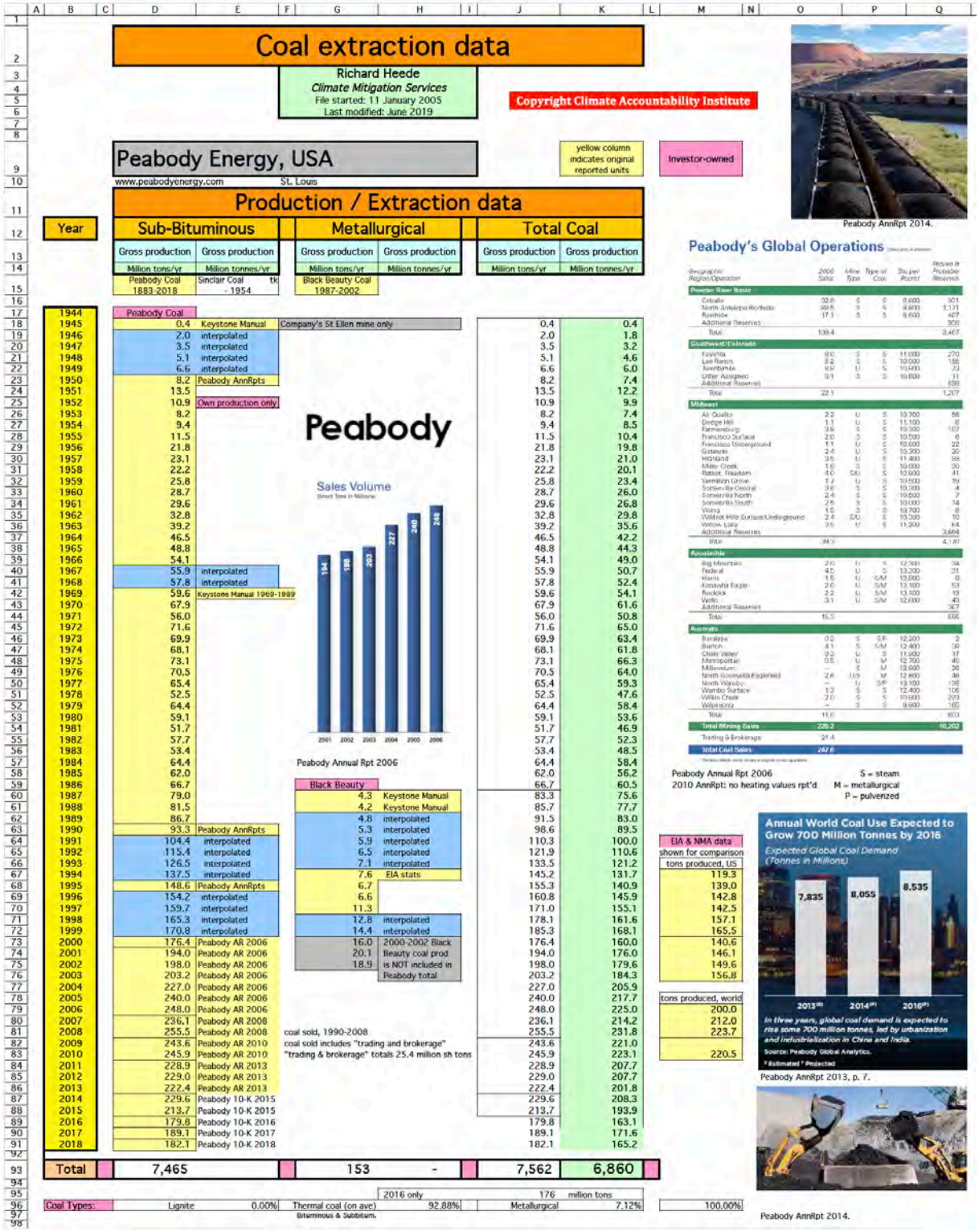
Screenshot of Chevron's cumulative scope 1 and scope 3 emissions, summed entity history from 1912 to 2017.

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.



	Successor		Predecessor	Combined
	Year Ended December 31, 2018	April 2 through December 31, 2017	January 1 through April 1, 2017	Year Ended December 31, 2017
	(Tons in millions)			
Powder River Basin Mining	120.3	94.0	31.0	125.0
Midwestern U.S. Mining	18.9	14.0	4.5	18.5
Western U.S. Mining	14.7	11.3	3.4	14.7
Seaborne Metallurgical Mining	11.0	9.5	2.2	11.7
Seaborne Thermal Mining	19.1	14.6	4.6	19.2
Total tons sold from mining segments	184.0	143.4	45.7	189.1
Corporate and Other	2.7	2.0	0.4	2.4
Total tons sold	186.7	145.4	46.1	191.5

Peabody Form 10-K for 2018, page 57. Note: CAI excludes "Trading and Brokerage."
page 53: In 2018, we produced and sold 182.1 million and 186.7 million tons of coal, respectively, from continuing operations.

Peabody's Leading Global Operations and Reserves

Peabody shipped 251.7 million tons of coal through sales, trading and brokerage activities in 2013 across North America, South America, Europe, Asia, Africa and Australia.

Geographic Region/Operation	2013 Tons Sold	Mine Type	Coal Type	Proven and Probable Reserves[1]
UNITED STATES				
Wyoming/Southern Powder River Basin				
Caballo	9.0	S	T	
North Antelope Rochelle	110.9	S	T	
Rawhide	14.2	S	T	
Southwest/Colorado				
El Segundo	8.4	S	T	
Kayenta	7.9	S	T	
Lee Ranch	0.1	S	T	
Twentymile	7.2	U	T	
Other U.S. West[2]	1.1			
Total U.S. West	158.8			4,141
Midwest				
Illinois				
Cottage Grove	1.9	S	T	
Gateway	2.8	U	T	
Wildcat Hills Underground	1.6	U	T	
Indiana				
Bear Run	8.2	S	T	
Francisco Underground	2.9	U	T	
Somerville Central	2.7	S	T	
Somerville North[3]	1.5	S	T	
Somerville South[3]	1.5	S	T	
Viking - Corning Pit[4]	1.1	S	T	
Wild Boar	2.0	S	T	
Other Midwest[2]	0.1			
Total U.S. Midwest	26.3			3,199
AUSTRALIA				
Queensland				
Burton	2.1	S	T/M	
Coppabella[5]	3.1	S	P	
Eaglefield	1.3	S	M	
Middlemount[6]	-	S	M/P	
Millennium	3.4	S	M/P	
Moorvale[5]	2.1	S	M/P	
North Goonyella	1.7	U	M	
New South Wales				
Metropolitan	1.4	U	M	
North Wambo Underground[7]	3.5	U	T/P	
Wambo Open-Cut[7]	2.6	S	T	
Wilpinjong	13.7	S	T	
Total Australia	34.9			925
Trading and Brokerage	31.7			
Total	251.7			8,265

Mine Type
U: Underground
S: Surface/Open-Cut

Coal Type
T: Thermal/Steam
M: Metallurgical
P: Pulverized Coal Injection (PCI)

Short tons in millions. Results from continuing operations.

[1] All bituminous ownership basis.
[2] Primarily consists of purchased coal used to satisfy certain specific coal supply agreements.
[3] Mines with an outside, non-controlling ownership interest.
[4] Expected to close in the first half of 2014.
[5] Held through a 73.9% undivided interest in an unincorporated joint venture.
[6] Held through a 50% equity interest in Middlemount Coal Pty Ltd. Because Middlemount is accounted for as an unconsolidated equity affiliate, 2013 tons sold from that mine have been excluded above.

Peabody Annual Report 2013, page 14.

Reserves

	2017			2016
	Successor	Predecessor	Combined	Predecessor
	April 2 through December 31	January 1 through April 1	Year Ended December 31	
			(Tons in millions)	
Powder River Basin Mining	94.0	31.0	125.0	113.1
Midwestern U.S. Mining	14.0	4.5	18.5	18.3
Western U.S. Mining	11.3	3.4	14.7	13.7
Australian Metallurgical Mining	9.5	2.2	11.7	13.4
Australian Thermal Mining	14.6	4.6	19.2	21.3
Total tons sold from mining segments	143.4	45.7	189.1	179.8
Trading and Brokerage	2.0	0.4	2.4	7.0
Total tons sold	145.4	46.1	191.5	186.8

Peabody Form 10-K for 2017, page 56.

U.S. Mining Operations - Powder River Basin, Midwestern, Western

Operations maps, 2017, USA and Australia

	Production			
Geographic Region / Mining Complex	Year Ended Dec. 31, 2013	Year Ended Dec. 31, 2012	Year Ended Dec. 31, 2011	Type of Coal
Midwest:				
Bear Run	8.2	7.9	6.5	T
Francisco Underground	2.9	2.8	3.0	T
Gateway	2.8	2.8	3.3	T
Somerville Central	2.6	2.3	3.0	T
Wild Boar	2.1	2.0	1.8	T
Cottage Grove	2.0	2.0	1.9	T
Wildcat Hills Underground	1.6	1.5	1.0	T
Somerville South	1.5	1.4	1.2	T
Somerville North	1.5	1.2	1.4	T
Viking - Corning Pit[4]	1.1	1.3	1.5	T
Willow Lake (Closed in 2012)	—	2.1	2.2	T
Total	26.3	27.3	26.8	
Powder River Basin:				
North Antelope Rochelle	111.0	107.6	109.1	T
Rawhide	14.2	14.7	15.0	T
Caballo	9.0	16.9	24.1	T
Total	134.2	139.2	148.2	
Southwest:				
El Segundo	8.7	8.8	8.1	T
Kayenta	7.2	7.5	8.1	T
Lee Ranch	—	1.3	2.0	T
Total	15.9	17.4	18.2	
Colorado:				
Twentymile	7.2	8.0	7.7	T
Australia:				
Wilpinjong	13.3	12.2	10.9	T
Wambo[7]	6.9	6.6	5.8	T/P
Millennium	3.5	3.2	1.9	M/P
Coppabella	3.2	2.8	0.4	P
North Goonyella / Eaglefield	2.3	4.1	2.2	M
Moorvale	2.1	1.9	0.3	M/P
Burton	2.0	1.2	2.1	T/M
Metropolitan	1.5	1.8	1.8	M
Middlemount[6]	—	—	—	M/P
Total	34.8	33.8	25.4	
Total Continuing Operations	218.4	225.7	226.3	
Discontinued Operations	4.0	3.3	2.6	
Total Assigned	222.4	229.0	228.9	

T: Thermal
M: Metallurgical
P: Pulverized Coal Injection

Peabody Annual Report 2013, page 34.

<5>
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

Antero	USA	oil & gas
Chesapeake	USA	oil & gas
Cloud Peak	USA	coal
Contura	USA	coal
Exxaro	South Africa	coal
EOG	USA	oil & gas
EQT	USA	oil & gas
Inpex	Japan	oil & gas
Noble	USA	oil & gas
Novatek	Russian Federation	coal
Obsidian	Canada	oil & gas
Petoro	Norway	oil & gas
PetroEcuador	Ecuador	oil & gas
Pioneer	USA	oil & gas
Santos	Australia	oil & gas
Southwestern	USA	oil & gas
TurkmenGaz	Turkmenistan	oil & gas
Wintershall	Germany	oil & gas
Woodside	Australia	oil & gas
YPF	Argentina	oil & gas

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

Adani Group	India	coal
Adaro Energy	Indonesia	coal
Alliance Resources	USA	coal
Astra	Indonesia	coal
Banpu	Thailand	coal
Bogatyr Coal	Kazakhstan	coal
Bumi Resources	Indonesia	coal
Canadian Oil Sands	Canada	bitumen
China Coal	China	coal
Datong Coal	China	coal
Indika Energy	Indonesia	coal
Inner Mongolia Yitai	China	coal
KuzbassRazrezUgol	Russian Federation	coal
Natural Resource Partners	USA	coal
Patriot Coal	USA	coal
PennWest	Canada	oil & gas
Severstal	Russian Federation	coal
Shaanxi Coal	China	coal
Shenhua Group	China	coal
Siberian Business Union	Russian Federation	coal
Siberian Coal Energy (SUEK)	Russian Federation	coal
Teck Resources	Canada	coal
VostSibogul	Russian Federation	coal
Whitehaven Coal	Australia	coal
WPX	USA	oil & gas

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.[6] 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.

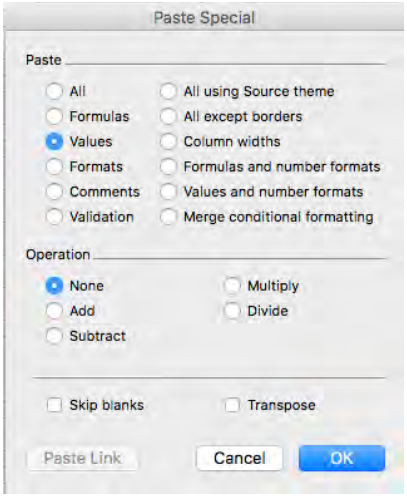
Mergers and acquisitions

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 CO_2 and CH_4

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 CO_2 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 $TgCH_4$ (3.63 $MtCO_2e$ at GWP value of $28xCO_2$, per AR4; equivalent to ~10% of global energy-related CO_2 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 CH_4 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.

<6>
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).

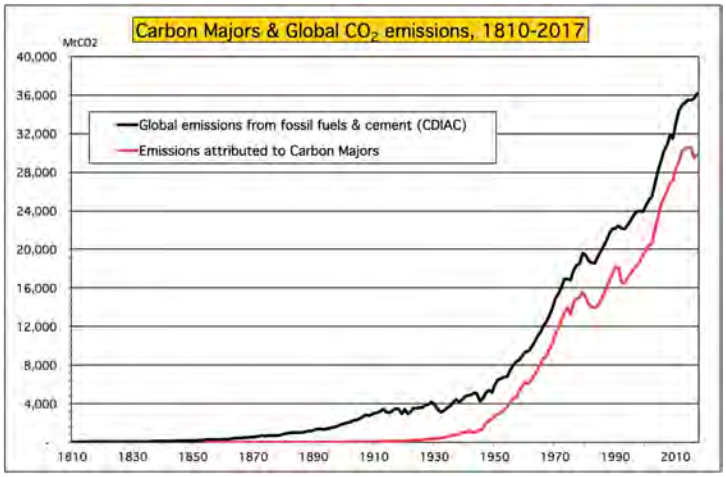


Fig. 23. Emissions attributed Carbon Majors and other (unattributed) producers of total CO_2 since 1751.

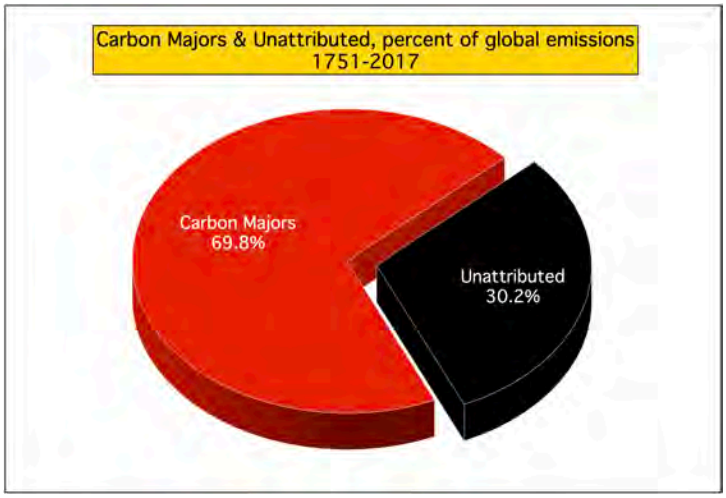


Fig. 24. Top Ten carbon major companies operational and product emissions 1965-2017

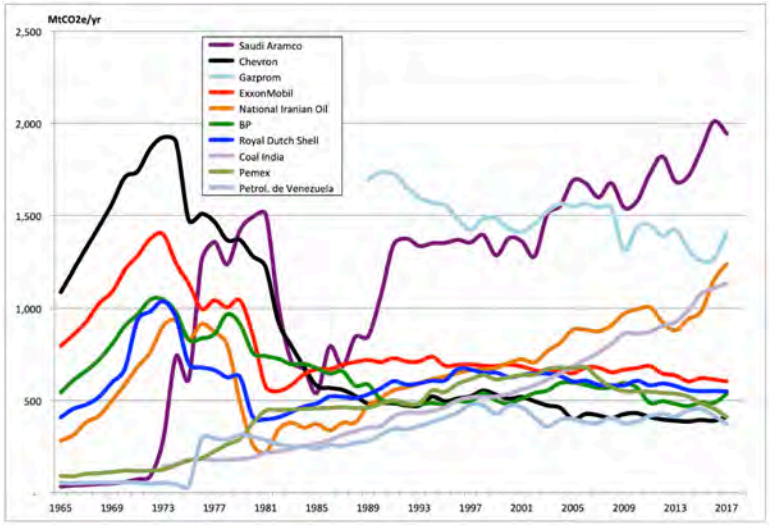


Fig. 25. Top Twenty carbon majors cumulative scope 1 and scope 3 emissions

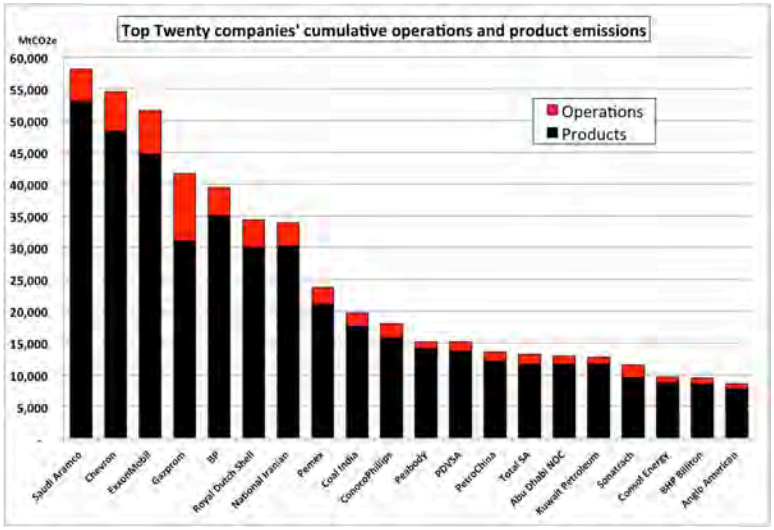


Fig. 26. Top Twenty carbon majors cumulative scope 1 and scope 3 emissions

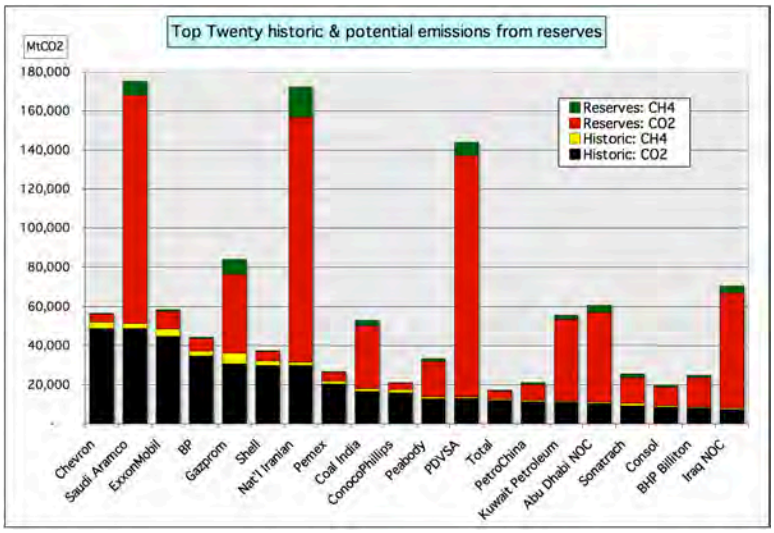
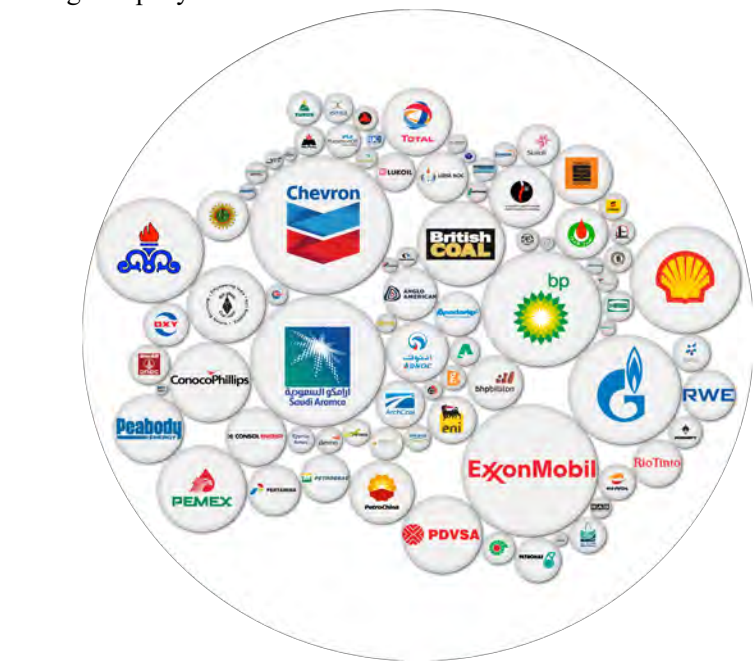


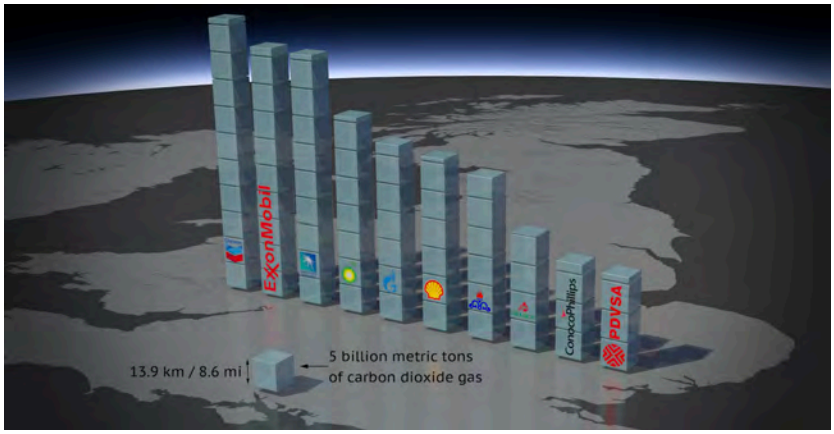
Table 9. Top Twenty carbon major companies operational and product emissions cumulative to 2017

	Entity	Product-related CO_2 $MtCO_2$	Flaring, own fuel, vented CO_2 $MtCO_2$	Fugitive methane $MtCO_2e$	Total emissions $MtCO_2e$	Percent of global 1751-2017
1.	Saudi Aramco, Saudi Arabia	54,364	1,346	3,820	59,530	3.40%
2.	Chevron, USA	48,513	1,560	4,723	54,796	3.13%
3.	ExxonMobil, USA	45,293	1,699	5,245	52,237	2.98%
4.	Gazprom, Russian Federation	32,281	2,638	8,311	43,230	2.47%
5.	BP, UK	35,451	1,136	3,452	40,039	2.29%
6.	Royal Dutch Shell, The Netherlands	33,085	1,240	3,829	38,154	2.18%
7.	National Iranian Oil Company	33,193	1,043	3,058	37,294	2.13%
8.	Pemex, Mexico	21,058	669	1,965	23,692	1.35%
9.	Coal India	20,079	0	2,347	23,126	1.35%
10.	ConocoPhillips, USA	15,962	714	2,169	18,846	1.08%
11.	Peabody Energy, USA	14,509	0	1,639	16,148	0.92%
12.	Petroleos de Venezuela	14,421	401	1,159	15,980	0.91%
13.	PetroChina, China	13,813	460	1,359	15,632	0.89%
14.	Total, France	12,788	445	1,321	14,554	0.83%
15.	Abu Dhabi	12,330	386	1,130	13,845	0.79%
16.	Kuwait Petroleum Corp.	12,634	299	841	13,774	0.79%
17.	Iraq NOC	11,729	251	695	12,675	0.72%
18.	Sonatrach, Algeria	10,239	519	1,592	12,351	0.71%
19.	BHP Billiton	8,794	87	1,013	9,894	0.57%
20.	CONSOL Energy	8,844	12	1,021	9,877	0.56%
	Sum of Top Twenty IOCs & SOEs	460,080	14,907	50,689	525,676	30.03%
	Global ind'l CO_2 & CH_4: 1751-2017	1,574,302		176,132	1,750,434	100.00%

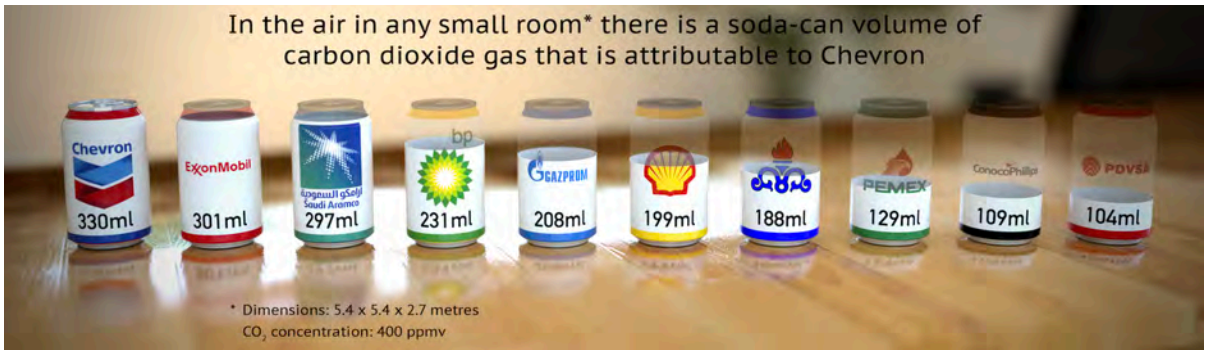
Innovative graphical ways to communicate

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





Courtesy of Antony Turner & Adam Nieman, Real World Visuals, Bristol, www.realworldvisuals.com, for CAI.



Courtesy of Antony Turner & Adam Nieman, Real World Visuals, Bristol, www.realworldvisuals.com, for CAI.

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

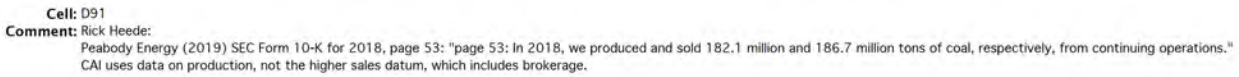
Production worksheets for all entities are extensively documented with sources, references, and various comments. Companies with deep histories, such as the Seven Sisters oil companies, may have six or more pages of cell notes. Every page and every cell note should be captured in the finished PDF for 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

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

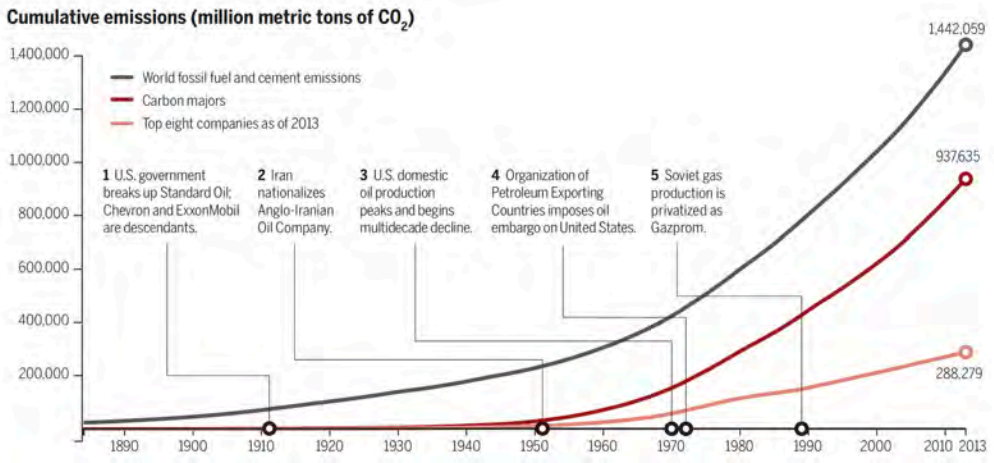
Analysts, climate modelers, scientists, and media may request and should be given access to the entire dataset or requested subsets, in excel if requested (particularly for scientific purposes). Otherwise, CAI recommends that inquiries should be directed to posted PDFs.

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



Courtesy of *Science* magazine, graphic by Jia You. In Starr (2016).

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*

Courtesy of *The Guardian*, image by Duncan Clark and Kiln. In Goldenberg (2013).

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 $MtCO_2$) by multiplying Mb times 0.3714 $MtCO_2$/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 $MtCO_2$. Likewise, Shell's "gas available for sale" in 2017 of 3,894 Bcf times 0.05343 $MtCO_2$/Mb equals estimated gas-related emissions of 208 $MtCO_2$. Shell's oil + gas production results in end-user emissions of 456 $MtCO_2$.

Table A1. Combustion emission factors

Energy source	Carbon tC/unit	Carbon dioxide tCO_2/unit
Crude oil & NGLs	101.4 kgC/bbl	371.4 $kgCO_2$/bbl
Natural gas	14.6 kgC/kcf	53.4 $kgCO_2$/kcf
Lignite	328.4 kgC/tonne	1,203.5 $kgCO_2$/t
Subbituminous	495.2 kgC/t	1,814.4 $kgCO_2$/t
Bituminous	665.6 kgC/t	2,439.0 $kgCO_2$/t
Anthracite	715.6 kgC/t	2,621.9 $kgCO_2$/t
"Metallurgical coal"	727.6 kgC/t	2,665.9 $kgCO_2$/t
"Thermal coal"	581.1 kgC/t	2,129.3 $kgCO_2$/t

Crude oil: prior to non-energy deduction & adjustment for NGLs: 115.7 kgC/bbl, 423.8 $kgCO_2$/bbl;
Gas: prior to non-energy deduction: 14.86 kgC/kcf ,or 54.44 $kgCO_2$/kcf; (kcf = thousand cubic feet).

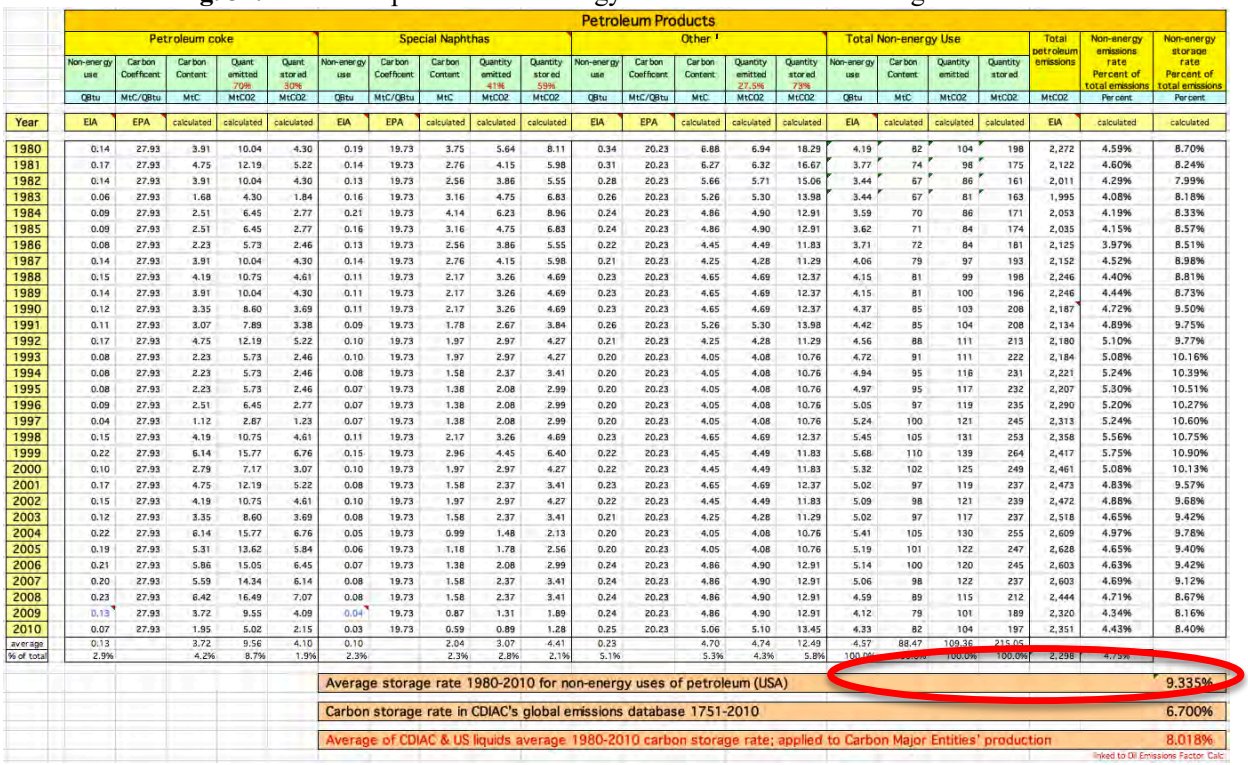
Oil, natural gas, and coal: Non-energy uses

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 CO_2 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

Product	Percent net non-energy use
Crude oil and NGLs	8.018%
Natural Gas	1.856%
Coal	0.016%

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



Petroleum Products

Year	Petroleum coke Non-energy use (QBtu) EIA	Petroleum coke Non-energy use (QBtu) EPA	Petroleum coke Carbon Content (MtC) calculated	Petroleum coke Quant emitted 70% (MtCO2) calculated	Petroleum coke Quant stored 30% (MtCO2) calculated	Special Naphthas Non-energy use (QBtu) EIA	Special Naphthas Non-energy use (QBtu) EPA	Special Naphthas Carbon Content (MtC) calculated	Special Naphthas Quantity emitted 41% (MtCO2) calculated	Special Naphthas Quantity stored 59% (MtCO2) calculated	Other Non-energy use (QBtu) EIA	Other Non-energy use (QBtu) EPA	Other Carbon Content (MtC) calculated	Other Quantity emitted 27.5% (MtCO2) calculated	Other Quantity stored 73% (MtCO2) calculated	Total Non-energy Use Non-energy use (QBtu) EIA	Total Non-energy Use Carbon Content (MtC) calculated	Total Non-energy Use Quantity emitted (MtCO2) calculated	Total Non-energy Use Quantity stored (MtCO2) calculated	Total petroleum emissions (MtCO2) EIA	Non-energy emissions rate Percent of total emissions calculated	Non-energy storage rate Percent of total emissions calculated
1980	0.14	27.93	3.91	10.04	4.30	0.19	19.73	3.75	5.64	8.11	0.34	20.23	6.88	6.94	18.29	4.19	82	104	198	2,272	4.59%	8.70%
1981	0.17	27.93	4.75	12.19	5.22	0.14	19.73	2.76	4.15	5.98	0.31	20.23	6.27	6.32	16.67	3.77	74	98	175	2,122	4.60%	8.24%
1982	0.14	27.93	3.91	10.04	4.30	0.13	19.73	2.56	3.86	5.55	0.28	20.23	5.66	5.71	15.06	3.44	67	86	161	2,011	4.29%	7.99%
1983	0.06	27.93	1.68	4.30	1.84	0.16	19.73	3.16	4.75	6.83	0.26	20.23	5.26	5.30	13.98	3.44	67	81	163	1,995	4.08%	8.18%
1984	0.09	27.93	2.51	6.45	2.77	0.21	19.73	4.14	6.23	8.96	0.24	20.23	4.86	4.90	12.91	3.59	70	86	171	2,053	4.19%	8.33%
1985	0.09	27.93	2.51	6.45	2.77	0.16	19.73	3.16	4.75	6.83	0.24	20.23	4.86	4.90	12.91	3.62	71	84	174	2,035	4.15%	8.57%
1986	0.08	27.93	2.23	5.73	2.46	0.13	19.73	2.56	3.86	5.55	0.22	20.23	4.45	4.49	11.83	3.71	72	84	181	2,125	3.97%	8.51%
1987	0.14	27.93	3.91	10.04	4.30	0.14	19.73	2.76	4.15	5.98	0.21	20.23	4.25	4.28	11.29	4.06	79	97	193	2,152	4.52%	8.98%
1988	0.15	27.93	4.19	10.75	4.61	0.11	19.73	2.17	3.26	4.69	0.23	20.23	4.65	4.69	12.37	4.15	81	99	198	2,246	4.40%	8.81%
1989	0.14	27.93	3.91	10.04	4.30	0.11	19.73	2.17	3.26	4.69	0.23	20.23	4.65	4.69	12.37	4.15	81	100	196	2,246	4.44%	8.73%
1990	0.12	27.93	3.35	8.60	3.69	0.11	19.73	2.17	3.26	4.69	0.23	20.23	4.65	4.69	12.37	4.37	85	103	208	2,187	4.72%	9.50%
1991	0.11	27.93	3.07	7.89	3.38	0.09	19.73	1.78	2.67	3.84	0.26	20.23	5.26	5.30	13.98	4.42	85	104	208	2,134	4.89%	9.75%
1992	0.17	27.93	4.75	12.19	5.22	0.10	19.73	1.97	2.97	4.27	0.21	20.23	4.25	4.28	11.29	4.56	88	111	213	2,180	5.10%	9.77%
1993	0.08	27.93	2.23	5.73	2.46	0.10	19.73	1.97	2.97	4.27	0.20	20.23	4.05	4.08	10.76	4.72	91	111	222	2,184	5.08%	10.16%
1994	0.08	27.93	2.23	5.73	2.46	0.08	19.73	1.58	2.37	3.41	0.20	20.23	4.05	4.08	10.76	4.94	95	118	231	2,221	5.24%	10.39%
1995	0.08	27.93	2.23	5.73	2.46	0.07	19.73	1.38	2.08	2.99	0.20	20.23	4.05	4.08	10.76	4.97	95	117	232	2,207	5.30%	10.51%
1996	0.09	27.93	2.51	6.45	2.77	0.07	19.73	1.38	2.08	2.99	0.20	20.23	4.05	4.08	10.76	5.05	97	119	235	2,290	5.20%	10.27%
1997	0.04	27.93	1.12	2.87	1.23	0.07	19.73	1.38	2.08	2.99	0.20	20.23	4.05	4.08	10.76	5.24	100	121	245	2,313	5.24%	10.60%
1998	0.15	27.93	4.19	10.75	4.61	0.11	19.73	2.17	3.26	4.69	0.23	20.23	4.65	4.69	12.37	5.45	105	131	253	2,358	5.56%	10.75%
1999	0.22	27.93	6.14	15.77	6.76	0.15	19.73	2.96	4.45	6.40	0.22	20.23	4.45	4.49	11.83	5.68	110	139	264	2,417	5.75%	10.90%
2000	0.10	27.93	2.79	7.17	3.07	0.10	19.73	1.97	2.97	4.27	0.22	20.23	4.45	4.49	11.83	5.32	102	125	249	2,461	5.08%	10.13%
2001	0.17	27.93	4.75	12.19	5.22	0.08	19.73	1.58	2.37	3.41	0.23	20.23	4.65	4.69	12.37	5.02	97	119	237	2,473	4.83%	9.57%
2002	0.15	27.93	4.19	10.75	4.61	0.10	19.73	1.97	2.97	4.27	0.22	20.23	4.45	4.49	11.83	5.09	98	121	239	2,472	4.88%	9.68%
2003	0.12	27.93	3.35	8.60	3.69	0.08	19.73	1.58	2.37	3.41	0.21	20.23	4.25	4.28	11.29	5.02	97	117	237	2,518	4.65%	9.42%
2004	0.22	27.93	6.14	15.77	6.76	0.05	19.73	0.99	1.48	2.13	0.20	20.23	4.05	4.08	10.76	5.41	105	130	255	2,609	4.97%	9.78%
2005	0.19	27.93	5.31	13.62	5.84	0.06	19.73	1.18	1.78	2.56	0.20	20.23	4.05	4.08	10.76	5.19	101	122	247	2,628	4.65%	9.40%
2006	0.21	27.93	5.86	15.05	6.45	0.07	19.73	1.38	2.08	2.99	0.24	20.23	4.86	4.90	12.91	5.14	100	120	245	2,603	4.63%	9.42%
2007	0.20	27.93	5.59	14.34	6.14	0.08	19.73	1.58	2.37	3.41	0.24	20.23	4.86	4.90	12.91	5.06	98	122	237	2,603	4.69%	9.12%
2008	0.23	27.93	6.42	16.49	7.07	0.08	19.73	1.58	2.37	3.41	0.24	20.23	4.86	4.90	12.91	4.59	89	115	212	2,444	4.71%	8.67%
2009	0.13	27.93	3.72	9.55	4.09	0.04	19.73	0.87	1.31	1.89	0.24	20.23	4.86	4.90	12.91	4.12	79	101	189	2,320	4.34%	8.16%
2010	0.07	27.93	1.95	5.02	2.15	0.03	19.73	0.59	0.89	1.28	0.25	20.23	5.06	5.10	13.45	4.33	82	104	197	2,351	4.43%	8.40%
average	0.13		3.72	9.56	4.10	0.10		2.04	3.07	4.41	0.23		4.70	4.74	12.49	4.57	88.47	109.36	215.05			
% of total	2.9%		4.2%	8.7%	1.9%	2.3%		2.3%	2.8%	2.1%	5.1%		5.3%	4.3%	5.8%	100.0%	100.0%	100.0%	100.0%	2,298	4.75%	

Average storage rate 1980-2010 for non-energy uses of petroleum (USA) 9.335%

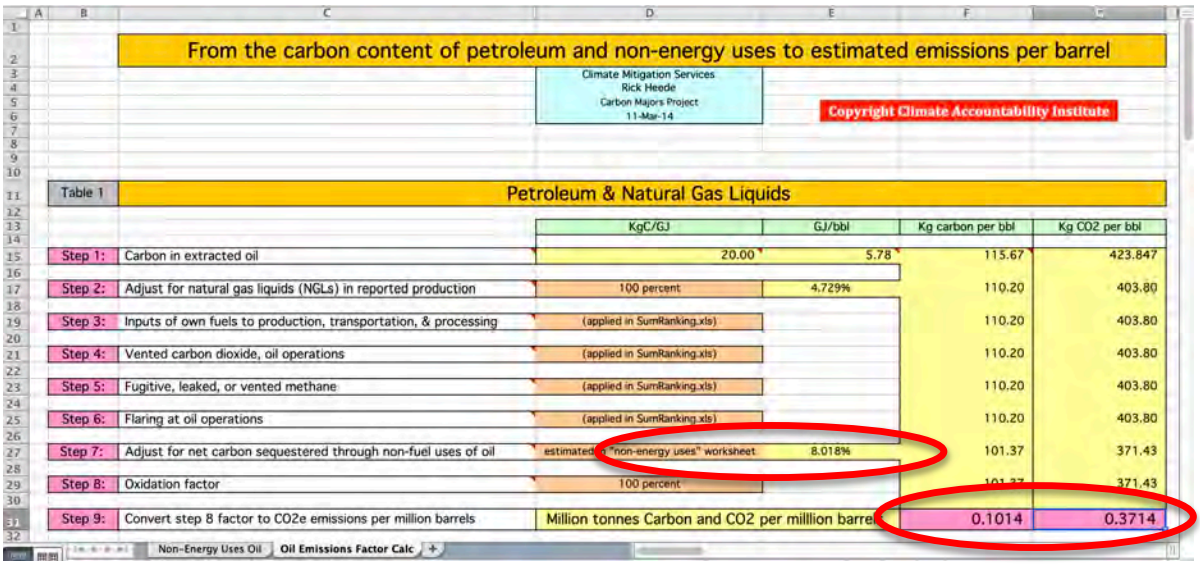
Carbon storage rate in CDIAC's global emissions database 1751-2010 6.700%

Average of CDIAC & US liquids average 1980-2010 carbon storage rate; applied to Carbon Major Entities' production 8.018%

linked to Oil Emissions Factor Calc

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)



From the carbon content of petroleum and non-energy uses to estimated emissions per barrel

Climate Mitigation Services
Rick Heede
Carbon Majors Project
11-Mar-14

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Table 1 — Petroleum & Natural Gas Liquids

		KgC/GJ	GJ/bbl	Kg carbon per bbl	Kg CO2 per bbl
Step 1:	Carbon in extracted oil	20.00	5.78	115.67	423.847
Step 2:	Adjust for natural gas liquids (NGLs) in reported production	100 percent	4.729%	110.20	403.80
Step 3:	Inputs of own fuels to production, transportation, & processing	(applied in SumRanking.xls)		110.20	403.80
Step 4:	Vented carbon dioxide, oil operations	(applied in SumRanking.xls)		110.20	403.80
Step 5:	Fugitive, leaked, or vented methane	(applied in SumRanking.xls)		110.20	403.80
Step 6:	Flaring at oil operations	(applied in SumRanking.xls)		110.20	403.80
Step 7:	Adjust for net carbon sequestered through non-fuel uses of oil	estimated in "non-energy uses" worksheet	8.018%	101.37	371.43
Step 8:	Oxidation factor	100 percent		101.37	371.43
Step 9:	Convert step 8 factor to CO2e emissions per million barrels	Million tonnes Carbon and CO2 per milllion barrel		0.1014	0.3714

Non-Energy Uses Oil | Oil Emissions Factor Calc

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 (Exxon-Mobil, then Standard Oil) to 2017. Scope 3 product-related emissions totaled 437 $GtCO_2$, or 78.5% of global oil and NGL emissions of 556 $GtCO_2$ from 1870-2017.

Three additional factors are added to cumulative emissions for each entity: CO_2 from flared associated gas, vented CO_2, and fugitive emissions of methane (CH_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 $GtCO_2$ for all Carbon Majors oil producers to 2017, including 24 $GtCO_2e$ of leaked and fugitive methane.

Scope 1 emissions: natural gas

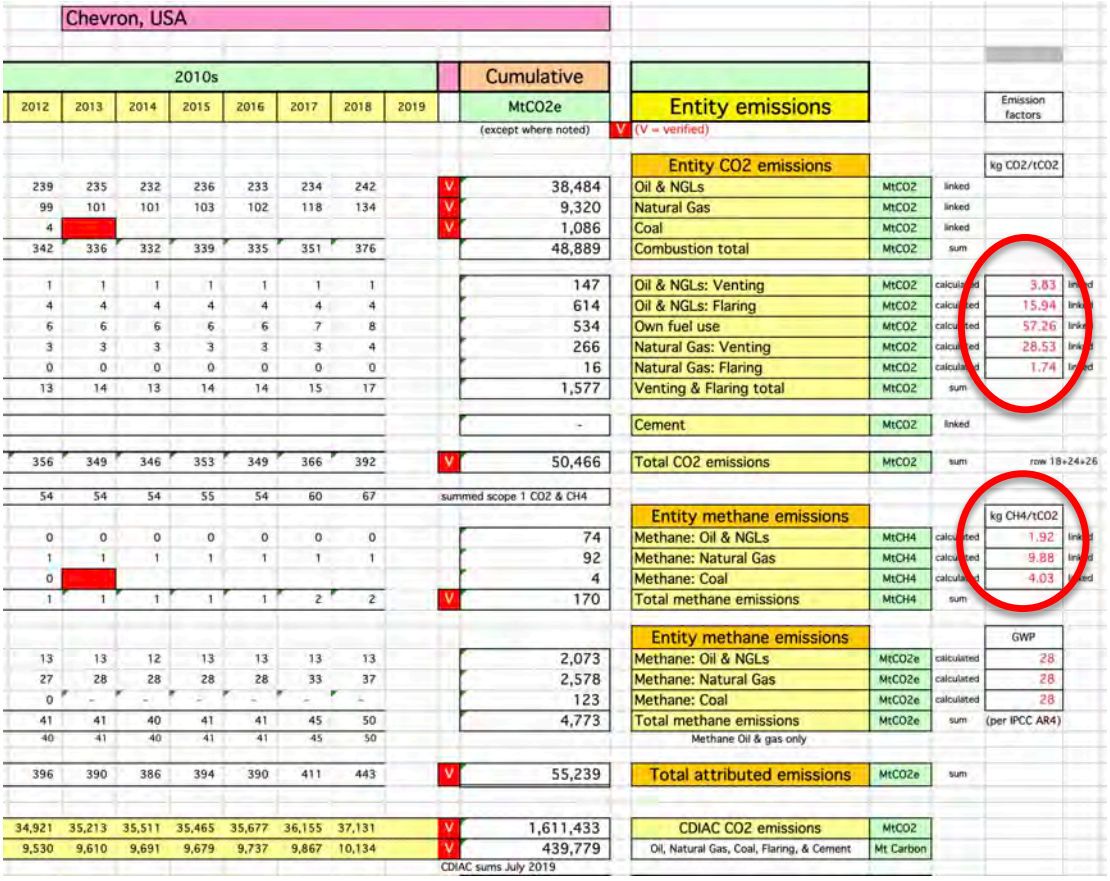
This project has quantified the extraction of 2,973 trillion cubic feet (Tcf) of natural gas by 74 entities from 1900 (for ExxonMobil, then Standard Oil) to 2017. Product-related emissions totaled 159 $GtCO_2$, equivalent to 71% of global gas emissions of 223 $GtCO_2$ 1885-2017.

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_2 from flared natural gas, CO_2 vented as process emissions (especially sour gas removal: CO_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.[7] The methodology for each factor is detailed in the *Methods & Results Report* (Heede 2013, 2019).

The Scope 1 emission sources total 58 $GtCO_2e$ for all Carbon Majors gas producers to 2017, including 44 $GtCO_2e$ of methane.

[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.

Fig. 36. Scope 1 operational emissions applied to Chevron, in "Entities AbuDhabi-Czech.xls"



Chevron, USA																
2010s									Cumulative							
2012	2013	2014	2015	2016	2017	2018	2019		MtCO2e (except where noted)	V	Entity emissions			Emission factors		
										V (V = verified)						
											Entity CO2 emissions			kg CO2/tCO2		
239	235	232	236	233	234	242			38,484	V	Oil & NGLs	MtCO2	linked			
99	101	101	103	102	118	134			9,320	V	Natural Gas	MtCO2	linked			
4									1,086	V	Coal	MtCO2	linked			
342	336	332	339	335	351	376			48,889		Combustion total	MtCO2	sum			
1	1	1	1	1	1	1			147		Oil & NGLs: Venting	MtCO2	calculated	3.83	linked	
4	4	4	4	4	4	4			614		Oil & NGLs: Flaring	MtCO2	calculated	15.94	linked	
6	6	6	6	6	7	8			534		Own fuel use	MtCO2	calculated	57.26	linked	
3	3	3	3	3	3	4			266		Natural Gas: Venting	MtCO2	calculated	28.53	linked	
0	0	0	0	0	0	0			16		Natural Gas: Flaring	MtCO2	calculated	1.74	linked	
13	14	13	14	14	15	17			1,577		Venting & Flaring total	MtCO2	sum			
									-		Cement	MtCO2	linked			
356	349	346	353	349	366	392			50,466	V	Total CO2 emissions	MtCO2	sum		row 18+24+26	
54	54	54	55	54	60	67			summed scope 1 CO2 & CH4							
											Entity methane emissions			kg CH4/tCO2		
0	0	0	0	0	0	0			74		Methane: Oil & NGLs	MtCH4	calculated	1.92	linked	
1	1	1	1	1	1	1			92		Methane: Natural Gas	MtCH4	calculated	9.88	linked	
0									4		Methane: Coal	MtCH4	calculated	4.03	linked	
1	1	1	1	1	2	2			170	V	Total methane emissions	MtCH4	sum			
											Entity methane emissions			GWP		
13	13	12	13	13	13	13			2,073		Methane: Oil & NGLs	MtCO2e	calculated	28		
27	28	28	28	28	33	37			2,578		Methane: Natural Gas	MtCO2e	calculated	28		
0	-	-	-	-	-	-			123		Methane: Coal	MtCO2e	calculated	28		
41	41	40	41	41	45	50			4,773		Total methane emissions	MtCO2e	sum	(per IPCC AR4)		
40	41	40	41	41	45	50					Methane Oil & gas only					
396	390	386	394	390	411	443			55,239	V	Total attributed emissions	MtCO2e	sum			
34,921	35,213	35,511	35,465	35,677	36,155	37,131			1,611,433	V	CDIAC CO2 emissions	MtCO2				
9,530	9,610	9,691	9,679	9,737	9,867	10,134			439,779	V	Oil, Natural Gas, Coal, Flaring, & Cement	Mt Carbon				
									CDIAC sums July 2019							

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 $GtCO_2$ 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 CH_4 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 $GtCO_2$, equivalent to 62% of global coal emissions of 742 $GtCO_2$ from 1751 to 2017.

The Scope 1 emission sources total 52 $GtCO_2$ for all Carbon Majors coal producers to 2017.

Scope 1 emissions summary

In Table B1 we add the ancillary emissions of estimated vented CO_2 (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 (CH_4). 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 $kgCO_2$ or $kgCO_2e$ per tonne of CO_2 from combustion of carbon fuel, by fuel source.

In Shell's case, these sources add 23.1 $MtCO_2$ and 2.53 $MtCH_4$ (equivalent to 70.9 $MtCO_2e$ at IPCC's AR5 global warming potential of $28xCO_2$). Shell's Scope 1 and Scope 3 emissions total 550 $MtCO_2e$ in 2017.

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

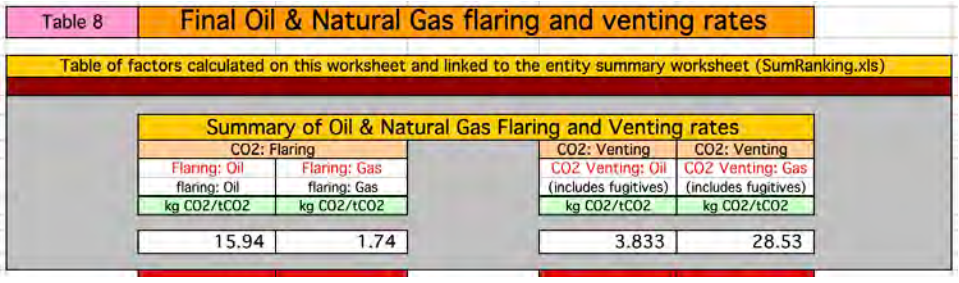
Entity	Combustion $kgCO_2/tCO_2$	Flaring $kgCO_2/tCO_2$	Vented $kgCO_2/tCO_2$	Methane $kgCH_4/tCO_2$	Methane $kgCO_2e/tCO_2$	Total $kgCO_2e/tCO_2$
Crude Oil & NGLs	1,000	15.94	3.83	1.92	58.36	1,073.6
Natural Gas	1,000	1.74	28.53	9.88	276.59	1,364.1
Coal	1,000	ne	ne	4.03	112.97	1,113.0

ne: not estimated; see text for discussion. Natural gas also includes own fuel use of 57.26 kg CO_2/tCO_2.

For crude oil and NGLs the aggregate emission factor for Scope 1 sources — flaring, vented CO_2, 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 CO_2 released from the high-temperature processing of limestone (calcium carbonate, $CaCO_3$) into clinker, the cementitious product that makes up Portland cement. This calcining process releases ~0.498 to 0.540 tCO_2/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 CO_2 emissions, including kiln dust, and either excluding or including emissions from energy inputs, depending on whether gross CO_2 are sought (such as by WBCSD Cement Sustainability Initiative and its members) or industrial CO_2 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 $GtCO_2$, or 60% of global cement emissions of 38 $GtCO_2$ 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 $GtCO_2$ 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.

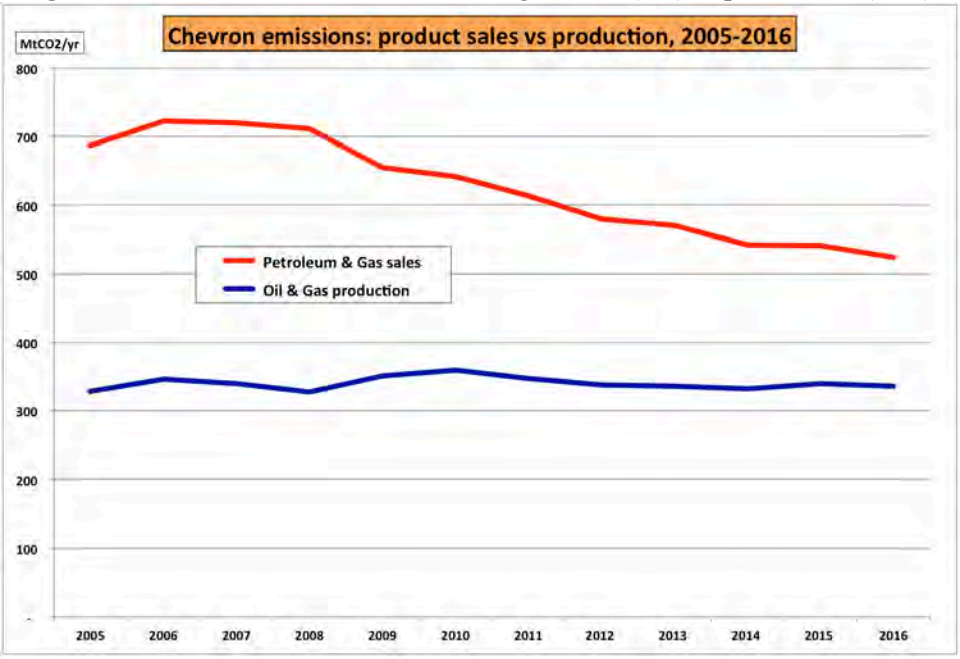
Scope 1 operational emissions comprise 11.5% of total attributed (Scope 1 + Scope 3) emissions. In our accounting through 2017 Scope 1 sources total 142 $GtCO_2e$ and product-related Scope 3 emissions total 1,079 $GtCO_2e$; S1 plus S3 equals 1,221 $GtCO_2e$. The Carbon Majors database and peer-reviewed 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 CO_2 and methane emissions are shown in Table C1.

Table C1. Top Twenty carbon major companies operational & product emissions cumulative to 2017.

	Entity	Product-related CO_2 $MtCO_2$	Flaring, own fuel, vented CO_2 $MtCO_2$	Fugitive methane $MtCO_2e$	Total emissions $MtCO_2e$	Percent of global 1751-2017
1.	Saudi Aramco, Saudi Arabia	54,364	1,346	3,820	59,530	3.40%
2.	Chevron, USA	48,513	1,560	4,723	54,796	3.13%
3.	ExxonMobil, USA	45,293	1,699	5,245	52,237	2.98%
4.	Gazprom, Russian Federation	32,281	2,638	8,311	43,230	2.47%
5.	BP, UK	35,451	1,136	3,452	40,039	2.29%
6.	Royal Dutch Shell, The Netherlands	33,085	1,240	3,829	38,154	2.18%
7.	National Iranian Oil Company	33,193	1,043	3,058	37,294	2.13%
8.	Pemex, Mexico	21,058	669	1,965	23,692	1.35%
9.	Coal India	20,079	0	2,347	23,126	1.35%
10.	ConocoPhillips, USA	15,962	714	2,169	18,846	1.08%
11.	Peabody Energy, USA	14,509	0	1,639	16,148	0.92%
12.	Petroleos de Venezuela	14,421	401	1,159	15,980	0.91%
13.	PetroChina, China	13,813	460	1,359	15,632	0.89%
14.	Total, France	12,788	445	1,321	14,554	0.83%
15.	Abu Dhabi	12,330	386	1,130	13,845	0.79%
16.	Kuwait Petroleum Corp.	12,634	299	841	13,774	0.79%
17.	Iraq NOC	11,729	251	695	12,675	0.72%
18.	Sonatrach, Algeria	10,239	519	1,592	12,351	0.71%
19.	BHP Billiton	8,794	87	1,013	9,894	0.57%
20.	CONSOL Energy	8,844	12	1,021	9,877	0.56%
	Sum of Top Twenty IOCs & SOEs	460,080	14,907	50,689	525,676	30.03%
	Global ind'l CO_2 & CH_4: 1751-2017	1,574,302		176,132	1,750,434	100.00%

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).



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Annex D, part 2
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Annex E
List of entities and worksheets

OIL & NGL & NATURAL GAS PRODUCERS	ANNO	# OF PAGES
Abu Dhabi NOC, UAE	1962-2018	6
Anadarko, USA	1945-2018	4
Apache, USA	1985-2018	2
Antero, USA	2012-2018	2
Bahrain Petroleum	1975-2018	4
BG Group, UK (acq by Shell Feb16)	1963-2015	2
BHP Billiton, Australia	1970-2018	4
BP, UK	1913-2018	10
Canadian Natural Resources	1988-2018	2
Chesapeake, USA	1994-2018	4
Chevron, USA	1912-2018	10
China National Offshore Oil/CNOOC (acq. Nexen)	1988-2018	2
ConocoPhillips, USA	1924-2018	10
Devon Energy, USA	1988-2018	4
Ecopetrol, Colombia	1987-2018	4
Egyptian General Petroleum	1959-2018	4
EnCana, Canada	1987-2018	2
Eni SpA, Italy	1950-2018	4
EOG, USA	1991-2018	4
EQT, USA	1992-2018	4
Equinor (frmly Statoil), Norway	1971-2018	6
ExxonMobil, USA	1882-2018	14
Former Soviet Union (oil, gas, coal)	1949-1991	4
Gazprom, Russian Federation	1989-2018	6
Hess, USA	1958-2018	4
Husky Energy, Canada	1988-2018	2
Inpex, Japan	2004-2018	4
Iraq National Oil Company	1960-2018	4
Kuwait Petroleum Corp.	1946-2018	6
Libya National Oil Corp.	1961-2018	4
Lukoil, Russian Federation	1996-2018	4
Marathon, USA	1938-2018	4
Murphy Oil, USA	1983-2018	4
National Iranian Oil Company	1928-2018	4
Nexen, Canada (acq by CNOOC Jan13)	1959-2012	4
Noble, USA	1992-2018	4
Nigerian National Petroleum	1987-2018	6
NorskHydro (see Statoil)	1987-2006	2
Novatek	2002-2018	4
Obsidian, Canada	1996-2018	4
Occidental, USA	1958-2018	4
Oil & Natural Gas Corporation, India	1959-2018	6
OMV Group, Austria	1997-2018	2
Pemex, Mexico	1938-2018	4
Pertamina, Indonesia	1959-2018	6
Petoro, Norway	1999-2018	4
Petrobras, Brazil	1954-2018	4
PetroChina, China	1988-2018	8
PetroEcuador	1991-2018	4
Petroleos de Venezuela	1960-2018	6
Petroleum Development Oman	1967-2018	6
Petronas, Malaysia	1959-2018	6
Pioneer, USA	1995-2018	4
Polish Oil & Gas, Poland	1998-2018	2
Qatar Petroleum	1959-2018	4
Repsol, Spain (acq. Talisman May 2015)	1964-2018	4
Rosneft, Russian Federation	1998-2018	4
Royal Dutch Shell, Netherlands	1892-2018	10
Santos, Australia	1991-2018	4

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	**ANNO**	**# OF PAGES**
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	**ANNO**	**# OF PAGES**
Cemex, Mexico	1990-2018	4
China (cement)	1928-2018	4
HeidelbergCement, Germany	1990-2018	4
Holcim, Switzerland (merged w Lafarge)	1990-2015	4
Italcimenti, 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 (acq 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
16.	Hess, USA	1958-2018	4
17.	Husky Energy, Canada	1988-2018	2
18.	Inpex, Japan	2004-2018	4
19.	Lukoil, Russian Federation	1996-2018	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
26.	Pioneer, USA	1995-2018	4
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
3.	China National Offshore Oil/CNOOC	1988-2018	2
4.	Ecopetrol, Colombia	1987-2018	4
5.	Egyptian General Petroleum	1959-2018	4
6.	Equinor (frmly Statoil), Norway	1984-2018	6
7.	Gazprom, Russian Federation	1989-2018	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
12.	Nigerian National Petroleum	1987-2018	6
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
19.	PetroEcuador	1991-2018	4
20.	Petroleos de Venezuela	1960-2018	6
21.	Petroleum Development Oman	1967-2018	6

22.	Petronas ,Malaysia	1959-2018	6
23.	Qatar Petroleum	1959-2018	4
24.	Rosneft, Russian Federation	1998-2018	4
25.	Saudi Aramco, Saudi Arabia	1938-2018	8
26.	Sibneft, Russian Fed. (see Gazprom)	1998-2004	0
27.	Sinopec, China	1999-2018	4
28.	Sonangol, Angola	1959-2018	4
29.	Sonatrach, Algeria	1964-2018	4
30.	Syrian Petroleum	1968-2018	4
31.	YPF, Argentina	2007-2018	2

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
10.	Cyprus Minerals, USA	1969-1998	2
11.	Exxaro, South Africa	1988-2018	4
12.	ExxonMobil, USA	1970-2002	2
13.	Glencore, Switzerland	1998-2018	2
14.	Kiewit Mining, USA	1944-2018	2
15.	Massey Energy, USA (acq. by Alpha NR Jun11)	1981-2011	4
16.	Murray Energy, USA	1988-2018	2
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
26.	UK Coal, UK (defunct Dec15)	1995-2015	2
27.	VistraEnergy (Luminant), USA	1977-2018	2
28.	Westmoreland Mining, USA	1854-2018	4

STATE-OWNED: COAL

1.	British Coal Corporation, UK	1947-1994	2
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
6.	North Korea (coal)	1980-2018	4
7.	Poland (coal)	1913-2018	4
8.	Russian Federation (coal)	1992-2018	4
9.	Ukraine (coal)	1992-2018	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 CO_2 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 CO_2 emissions but typically combine emissions from fossil fuel inputs, such as coal or petroleum coke, and the CO_2 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 ($CaCO_3$) in a kiln reduces to lime (CaO) and CO_2;

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))

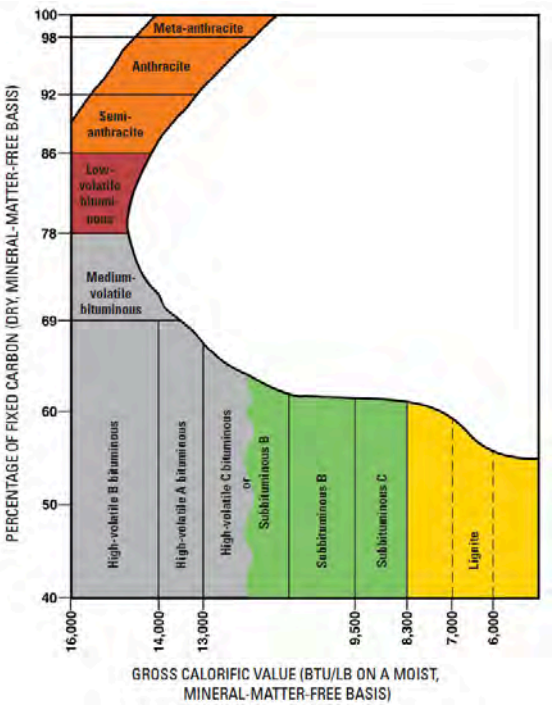
Sub-bituminous; medium rank coal used primarily for raising steam at powerplants, 20 to 30% moisture content, 20 to 24 MJ/kg (US: 17 to 24 MBtu/sht)

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

Table F1. Conversion factors

1 tonne crude oil	7.33 bbl
1 bbl	42 gallons & 159 liters
1 cubic meter natural gas STP	35.315 cubic feet
1 tonne	1.0231 short ton
1 tonne CO_2 (STP)	10.3 meter diameter sphere
1 tonne LNG	~48,700 cf or ~1,380 m^3
1 billion tCO_2/yr	31.7 tCO_2/sec
1 gallon	3.785 liters
1 gram of methane	28 gCO_2 equiv.

For energy conversions see United Nations, World Resources Institute, International Energy Agency, BP Statistical Annual.

For climate conversions and factors, see IPCC AR5, US EPA , IPCC 2006 *Guidelines*.

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